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Canada Centre for Mineral and Energy Technology
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Mining Research Laboratories
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Canada/NB MDA Project on Mine-shaft Rope Testing; testing of 1 3/4 in., 6×25, R. S., H. R., (our rope #10)

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MRL 91-002 (TR)

January, 1991

Canada

91-05143/

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48 pp

MICROMEDIA

CANADA/NB MDA PROJECT ON MINE-SHAFT ROPE TESTING; TESTING OF 1 3/4 in., 6×25, R. S., H. R. (OUR ROPE #10)

by

L.B. Geller*, D. Poffenroth†, J.E. Udd**, and D. Hutchinson††

ABSTRACT

In this report the authors analyse the test-results obtained non-destructively on a 1 3/4 in. diameter, round-strand (R. S.), hoist-rope (H.R.). The rope was examined both in-situ and on the shop-floor as part of CANMET's project to comparatively evaluate the performance of a range of EM wire-rope testers. This is the first time that a project of this magnitude and diversity has been undertaken.

The rope, when tested in-situ by its owners (INCO) with a Rotesco AC instrument, was reported to contain a maximum strength loss (LBS_{max}) of 9.5% at 1,350 ft from the skip. On the shop-floor the rope was tested, reel-to-reel, with the Canadian Magnograph and Rotescograph, the American LMA-250, and the German WBK instruments. Maximum estimated LBS was reported at 10.0% by the Rotescograph operator, and at 16.0% by the Magnograph operator. The operators of the American and German instruments did not submit LBS estimates.

The results obtained are analysed with special reference to such important parameters as their repeatability, comparability, and levels of accuracy.

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Keywords: New Brunswick; Mineral Development Agreement; Wire-ropes; Non-destructive-testing; Electro-magnetic instruments; Hoist-ropes

PROJET D'EÉM CANADA/NB SUR DES ESSAIS DE CÂBLES DE PUITS DE MINE; ESSAI D'UN CÂBLE DE LEVAGE DE 1,75 PO À 6X25 TORONS RONDS (NOTRE CÂBLE NO 10)

par

L.B. Geller[1], D. Poffenroth[2], J.E. Udd[3] et D. Hutchinson[4]

RÉSUMÉ

Dans le présent rapport, les auteurs analysent les résultats d'essais tant destructifs que non destructifs sur un câble de lavage (CL) de 1,75 po de diamètre à 6x25 torons ronds (TR). Le câble a été examiné sur place et à l'atelier dans le cadre du projet de CANMET visant à évaluer le rendement d'une gamme d'appareils ÉM d'essai de câbles métalliques. C'est la première fois qu'un projet de cette envergure et de cette diversité est entrepris.

Le câble, lorsqu'essayé sur place par ses propriétaires (INCO) au moyen d'un appareil c.a. Rotesco aurait présenté une perte de résistance maximum (PRR_{max}) de 9,5 % à 1 350 pieds du monte-charge. À l'atelier, le câble a été mis à l'essai au moyen des instruments canadiens Magnograph et Rotescograph, américain LMA-250 et allemand WBK. La PRR maximum a été estimée à 10,0 % par l'opérateur du Rotescograph et à 16,0 % par l'opérateur du Magnograph. Les opérateurs des instruments américain et allemand n'ont pas fourni d'estimations de la PRR.

Les résultats obtenus sont analysés, notamment eu égard à des paramètres aussi importants que leur répétabilité, leur comparabilité et leurs niveaux de précision.

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Mots clés: Nouveau-Brunswick; entente sur l'exploitation minérale; câbles métalliques; essai non destructif; instruments électromagnétiques; câbles de levage

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BACKGROUND

The results described in this report constitute an integral part of the contracted phase of CANMET's project, undertaken in 1986 in response to requests by both the mining industry and the mine regulatory authorities. The basic project objectives specified that the continuing rope failures, or near failures — occurring despite mandatory wire-rope examinations with electro-magnetic (EM) instruments at regular intervals — be examined, documented, analysed, and the reasons for these occurrences clarified. This is the first time a project of this scope and depth has been undertaken, anywhere.

CANMET's work included both in-house and contracted work phases. The in-house phase resulted in a range of conclusions and recommendations, reported elsewhere (references 1 through 4). We are now in the process of reporting the results obtained during the contracted project-phase, which included an extensive series of both in-situ and shop-floor tests. The first twelve reports to describe this project phase were published in the period February, 1990, through January, 1991 (references 5 through 16). More are to follow.

ROPE DETAILS

The rope which is the subject of this report (referred to as "our rope #10") was used as a skip hoist-rope in Compartment #1, Shaft #3, of INCO's Frood mine near Sudbury, Ontario. It was a 1 3/4 in. diameter, 6 × 25, R.S., RLL, FC, rope of 3,700 ft length, rope #909544-01-1, reel #540080-1, with a mass of 4.9 lb/ft. It was manufactured on 1985 04 18*; installed on 1987 03 02, and removed on 1988 10 24 (i.e., a service life of $19\frac{1}{2}$ months). Its original breaking strength was 313,500 lb, per Ontario MOL certificate #65686 of 1985 11 15. Its construction was: 12× 0.117 in. outers; 6× 0.052 in. fillers; 6× 0.121 in. inners; and 1× 0.126 in. centre.

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*: dates are given in this order: year, month, day

IN-SITU TEST RESULTS — AS REPORTED AND REVIEWED

The Rotesco AC data

The in-situ tests were undertaken, under standard operating conditions, by INCO staff with their Rotesco AC instrument. The maximum LBS (i.e., LBS_{max}) estimates were: 1.5% at 1,670 ft from the skip on 1987 08 25; 4.0% at 1,630 ft from the skip on 1987 12 08; 7.0% at 1,520 ft from the skip on 1988 05 09; and 9.5% at 1,350 ft from the skip on 1988 09 26. The weight of the conveyance was 13,520 lb, and the total load 49,657 lb. The EM tests were performed by INCO staff with the approval of the instrument maker and the regulatory authorities.

A copy of the operator's latest (test #F-622) strip-chart is reproduced in Fig. 1a. In Fig. 1b we provide another copy of this chart, as aligned and marked by us with the 0.0% LMA reference level and several characteristic rope-defect locations. Tested rope-length was 2,480 ft. The relevant data are tabulated in Table 1.

We agree with the operator's results, *per se*.

SHOP FLOOR TEST RESULTS — AS REPORTED AND REVIEWED

General procedure

The shop-floor tests were undertaken with two Canadian (the Rotescograph and Magnograph), one American (the LMA-250), and a West German tester (the prototype version of the latest German WBK instrument). The operators were known to, and approved by, the instrument makers/designers. None of them knew about each other's results before these were submitted to us. All details of the shop-floor testing process have been described, and illustrated, elsewhere (5).

The Magnograph data

Shop-floor testing with the Magnograph was undertaken on 1989 04 04. The operator reported an LMA_{max} of 5.5% (report #89-286A) between 584-714 yards, and 1109-1195 yards from start of the test at the drum rope-end. The test-chart is reproduced in Fig. 2, complete with our own marking of the 0.0% LMA level and the characteristic rope-defects 'X', 'Y', and 'Z'. The rope length tested was 3,585 ft. The

operator only marked the 5.5% LMA_{max} reading on his chart. While no other LMA readings were marked, the location of seven local faults were noted.

The operator also submitted an LBS estimate of 16.0% for the 610-612 yard (1,830-1,836 ft) rope segment, i.e., for the one containing rope defects 'Z_1' and 'Z_2'.

We agree with the operator's report, *per se*.

The LMA-250 data

Shop-floor testing with the LMA-250 instrument was performed on 1989 04 04. The rope length tested was 2,816 ft. Testing commenced at the drum rope-end. The 0.0% LMA was at the drum rope-end. The LMA difference between the two rope-ends was 1.8%.

The operator submitted a report, and marked the chart with: (a) the 0.0% LMA level, (b) the location of the seizing-wire rope-markers M_1 to M_{15} (these are conspicuous on both the LF and LMA chart-traces), (c) a number of LMA chart readings, and (d) some, but not all, of the broken wires detected. We reproduce this chart in Fig. 3, complete with our own markings of the 100% reference level and of characteristic rope-defect locations 'X', 'Y', and 'Z'. The operator's report also contains comments on apparent corrosion between markers M_8 – M_9 and M_{14} – M_{15}.

We agree with the operator's report, *per se*.

The Rotescograph data

Shop-floor testing with the Rotescograph was first performed on 1989 04 04 with test-start at the skip rope-end (Fig. 4a), and a second time on 1989 04 10 with test-start at the drum rope-end (Fig 4b). According to the strip-charts the rope length tested was 3,470 ft and 3,570 ft, respectively. The 0.0% LMA level was at the drum rope-end, on both occasions. The LMA difference between the two rope-ends was 1.2% on the first, and 0.8% on the second occasion. On both occasions the operator marked the seizing-wire locations — which showed up well on both the LMA and LF chart-traces. However, the rope-advance footages and LMA readings were only marked on the 1989 04 10 chart (Fig. 4b). Here the LMA_{max} chart-reading was marked as being 5.0% at 1,850 ft from the drum rope-end (i.e., at defect 'Z_2'). We added our own 100% reference level and rope defect location markings to the operator's charts.

We agree with the operator's chart-readings, *per se*.

The operator also submitted LBS estimates. These were calculated by doubling the respective LMA chart-readings at the corresponding rope-locations.

The WBK data

Shop-floor testing was performed on 1989 04 10 with the German WBK instrument — concurrently with the Rotescograph test-run. The rope length tested was 3,612 ft (1,101 m). The strip-chart contains, reading from top-to-bottom: five LF traces, a %LMA trace, and a length indication scale (in meters). There is also space for a second %LMA trace and for a rope-diameter indication-trace (not used in the current test-series). With the sensor-head closed, the individual measuring coils LF #1 and LF#2 were joined together, and so were #3 and #4. The fifth LF chart-trace summarizes the output of these two individual traces. Surface defects, such as the seizing-wire markers, were particularly conspicuous on this instrument's LF and LMA traces.

The two WBK operators carefully annotated their charts, including some LMA readings and the seizing-wire marker (M1 to M15) locations. They also submitted a report. Testing commenced at the skip rope-end. The LMA difference between the two rope-ends was 1.2%.

We did not receive a copy of the complete strip-chart. Instead copies of the important chart sections were submitted, numbered Figures 10.1 to 1.24, inclusive. We reproduce these as our Fig. 5. As may be seen, the 0.0% LMA reference level was set along the 1,090–1,098 m rope section at the drum rope-end; the %LMA scale was 0.287% per mm of full-scale diagram (see 'Fig. 10.1' of our Fig. 5). We added our own marking of the 'X', 'Y', and 'Z' rope defect locations, and the height of the %LMA chart-spikes at the seizing-wire markers. Test results are tabulated in Table 1.

The German report included a tabulation of the M1 to M15 marker locations. It is interesting to note that the tabulated distance between these markers was consistently 76 m (249.3 ft). The corresponding 'true' distance was 250 ft. We agree with the operators' report, *per se*.

ANALYSIS OF TEST RESULTS

(1) General comments

We tabulated both the in-situ and shop-floor chart-readings in Table 1. Details of the test set-ups are listed in Table 2. Considering the influence of the instrument calibration-procedures upon the test-results, we included relevant information about these matters in Table 1, such as: (a) the rope-end at which calibration was effected, (b) the rope-end at which 0.0%LMA was found to be, and (c) the %LMA difference between the two rope-ends.

The rope-markers M1–M15 are very helpful in providing accurately located "fingerprints" for comparing the respective %LMA chart readings of the various EM instruments. Moreover, the height of the LMA 'spikes' produced by them provide a useful basis for comparing the quantitative resolution of the EM testers.

Wherever we were unable to reproduce the strip-charts in a single length, we provided match-marks (such as: ref. 'A'; ref. 'B'; etc.) on the individual chart-segments. Moreover, we added to all charts: (a) the 100% reference levels, (b) the relevant sensitivity scales (%LMA per major chart-division), (c) the 'X', 'Y', and 'Z' rope defect locations and (d) the %LMA chart-readings at the most important rope-locations.

(2) LF chart-readings:

Broken wires showed up quite consistently on the LF-traces of all the instruments. The WBK traces were particularly explicit in case of surface flaws. We listed the LF chart locations in Table 3.

(3) LMA chart readings

The %LMA chart-readings were, on the whole, in fair agreement. The rope was in a relatively good condition, with none of the %LMA values exceeding 6.8%.

There were a number of natural "fingerprints" by means of which it was easy to positively identify, and compare, the in-situ and shop-floor chart-traces. We identified these as defects 'X', 'Y', and 'Z' on the instrument charts. Comparative evaluation of the five EM instruments used can, perhaps, be best based on the LMA chart-readings (Table 1) obtained at the fifteen seizing-wire rope-marker locations M1 to M15. These markers consisted of $\frac{1}{16}$ in. diameter wire, wound around the $1\frac{3}{4}$ in. rope at 250 ft intervals along 2 in. stretches. Noting that the metallic cross-sectional area (A) of the rope itself was assumed to be 1.2714 in^2, addition of the seizing-wire represented a metallic area increase of some 21%. It will be noted that in Table 1 we listed both the %LMA chart-readings, and the height of the LF trace perturbations (i.e., 'spikes'), at these markers. The 'spikes' on the WBK chart-traces are particularly conspicuous.

In this context, though, we must also emphasize the different quantitative resolution of the five instruments, exemplified, as an example for the Magnograph, by Fig. 32c in ref. 5.

(4) LBS estimates

Since no destructive tests were performed on this rope within the context of our project, we had no way of checking the accuracy of the operators' LBS estimates.

Interestingly, though, the LBS_{max} estimates ranged from 9.5% to 16.0%. Specifically:

(a) the Rotesco AC operator reported: 9.5% at 1,350 ft from the skip rope-end, with a corresponding LMA of 4.9% (Fig. 1);

(b) the Magnograph operator reported: 16.0% at 1,749 ft from the skip rope-end, with a corresponding LMA of 5.5% (Fig. 2);

(c) the Rotescograph operator reported: 10.0% at 1,720 ft from the skip rope-end, with a corresponding LMA of 5.0% (Fig. 4b).

(5) Comparability: in-situ vs shop-floor test results

The in-situ and shop-floor LMA chart-readings in Table 1 are in fair agreement. This supports the previously stipulated contention (11) that in-situ and reel-to-reel EM tests can be legitimately compared.

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APPENDIX 1

Tables 1, 2, and 3

as well as Figures 1 to 5, inclusive

Table 1

In situ and shop-floor test-results

Subject	In-situ Rot. AC 1988 09 26 Fig. 1	Shop-floor Magnogr. 1989 04 04 Fig. 2	LMA-250 1989 04 04 Fig. 3	Rotescogr. 1989 04 04 Fig. 4a	Rotescogr. 1989 04 10 Fig. 4b	WBK 1989 04 10 Fig. 5
tested rope length	2,480 ft	3,585 ft	2,816 ft	3,470 ft	3,570 ft	3,612 ft
%LMA:						
@ 'X'	3.1%	4.7%	5.1%	3.8%	3.0%	4.5%
@ ft*	105 ft	96 ft	105 ft	100 ft	110 ft	115 ft
@ 'Y_1'	3.9%	5.5%	6.8%	4.6%	4.0%	6.0%
@ ft*	1340 ft	1,560 ft	1,250 ft	1,515 ft	1,555 ft	1,565 ft
@ 'Y_2'	4.9%	5.5%	6.5%	4.6%	4.0%	6.0%
@ ft*	1,365 ft	1,575 ft	1,260 ft	1,535 ft	1,575 ft	1,583 ft
@ 'Z_1'	3.5%	4.8%	6.8%	4.3%	4.2%	6.0%
@ ft*	1,500 ft	1,737 ft	1,360 ft	1,665 ft	1,705 ft	1,724 ft
@ 'Z_2'	5.1%	6.0%	7.6%	5.0%	5.0%	6.3%
@ ft*	1,515 ft	1,752	1,370 ft	1,685ft	1,720 ft	1,739 ft
@ 'Z_3'	3.6%	4.2%	5.5%	3.4%	3.6%	5.0%
@ ft*	1,535 ft	1,770 ft	1,390 ft	1,705 ft	1,750 ft	1,763
@ 'Z_4'	4.0%	4.6%	6.0%	4.0%	4.2%	5.0%
@ ft*	1,550 ft	1,788 ft	1,400 ft	1,720 ft	1,765ft	1,777 ft
calib. @:						
skip;	yes	—	—	yes	—	yes
drum;	—	yes	yes	—	yes	—

Table 1 (continued)

In situ and shop-floor test-results

Subject	In-situ Rot. AC 1988 09 26 Fig. 1	Shop-floor Magnogr. 1989 04 04 Fig. 2	LMA-250 1989 04 04 Fig. 3	Rotescogr. 1989 04 04 Fig. 4a	Rotescogr. 1989 04 10 Fig. 4b	WBK 1989 04 10 Fig. 5
tested rope length	2,480 ft	3,585 ft	2,816 ft	3,470 ft	3,570 ft	3,612 ft
0.0% LMA @:	450'-900' to skip	drum	drum	drum	drum & 370'-1270' to skip	drum
%LMA diff. betw. ends:	0.2%	1.8%	1.8%	1.2%	0.8%	1.2%
%LMA chart-read & (spike-height) @:						
$M_1^{\dagger}$	—	0.8%;(0.8%)$^{\bullet}$	0.0%;(0.8%)	0.0%;(0.2%)	0.2%;(0.4%)	0.0%;(1.7%)
M_2	—	1.0%;(0.8%)	0.5%;(1.0%)	0.1%;(0.5%)	0.5%;(0.6%)	0.0%;(3.2%)
M_3	—	1.0%;(0.8%)	1.0%;(1.0%)	0.6%;(0.5%)	0.9%;(0.5%)	—
M_4	—	1.0%;(0.8%)	1.0%;(1.0%)	0.6%;(0.5%)	0.9%;(0.6%)	—
M_5	—	0.7%;(0.8%)	1.0%;(1.0%)	0.6%;(0.6%)	1.0%;(0.6%)	—
M_6	—	1.0%;(0.8%)	1.0%;(1.0%)	0.6%;(0.5%)	1.2%;(0.4%)	—
M_7	—	1.0%;(0.8%)	1.0%;(1.0%)	0.5%;(0.6%)	1.0%;(0.7%)	—
M_8	—	1.5%;(0.8%)	1.2%;(0.7%)	0.5%;(0.5%)	1.2%;(0.5%)	0.4%;(2.6%)
M_9	—	1.8%;(0.8%)	1.5%;(1.2%)	1.1%;(0.7%)	0.6%;(0.7%)	1.1%;(3.0%)
M_{10}	—	1.9%;(0.8%)	1.5%;(1.2%)	1.3%;(0.6%)	0.5%;(0.6%)	—
M_{11}	—	1.9%;(0.8%)	1.5%;(1.0%)	1.5%;(0.4%)	0.6%;(0.5%)	1.4%;(2.6%)
M_{12}	—	2.0%;(0.8%)	0.8%;(1.0%)	1.1%;(0.4%)	0.3%;(0.5%)	—
M_{13}	—	1.9%;(0.8%)	1.0%;(1.0%)	0.9%;(0.6%)	0.1%;(0.6%)	0.6%;(3.2%)
M_{14}	—	2.0%;(0.8%)	1.2%;(1.3%)	1.0%;(0.6%)	0.4%;(0.7%)	—
M_{15}	—	2.5%;(0.8%)	2.5%;(0.8%)	2.2%;(0.4%)	1.2%;(0.5%)	1.7%;(2.6%)

*: from the skip rope-end

†: closest to the drum rope-end

•: all 0.8% Magnograph readings too small for accuracy; but clear LF perturbations

Table 2

Details of EM testing of the $1\frac{3}{4}$ in., 6×25, H.R.

Item No.	Test Instr.	Test No.	Test date	Test location	Instr. operator*	Test chart: Fig. #
1	Rotesco AC	#F-662	1989 09 26	in-situ	(4)	1a
2	Magnograph	#89-286A	1989 04 04	shop-floor	(2)	2
3	LMA-250	—	1989 04 04	shop-floor	(5)	3
4	Rotescograph	ME-0013KPN	1989 04 04	shop-floor	(6)	4a
5	Rotescograph	—	1989 04 10	shop-floor	(6)	4b
6	WBK	—	1989 04 10	shop-floor	(7)	5

* (7): instr. designer/maker and service company
(2) service company
(4) and (6): mining company
(5) government organization

TABLE 3

Major LF locations on strip-charts and/or reported

Distance from skip rope-end (ft)				
Magnograph Fig. 2	LMA-250 Fig. 3	Rotescograph Fig. 4a	Rotescograph Fig. 4b	WBK Fig. 5
1,359	1,111	1,370	1,335	1,381
1,443	1,116	1,495 to	1,460 to	1,502
1,524		1,555	1,565	1,594 to
1,548		(numerous)	(numerous)	1,844
	2,170		1,855	(numerous)
	2,450		2,395	
			2,698	
2,898		2,790	2,945	2,812
3,210		3,140	3,039	3,166

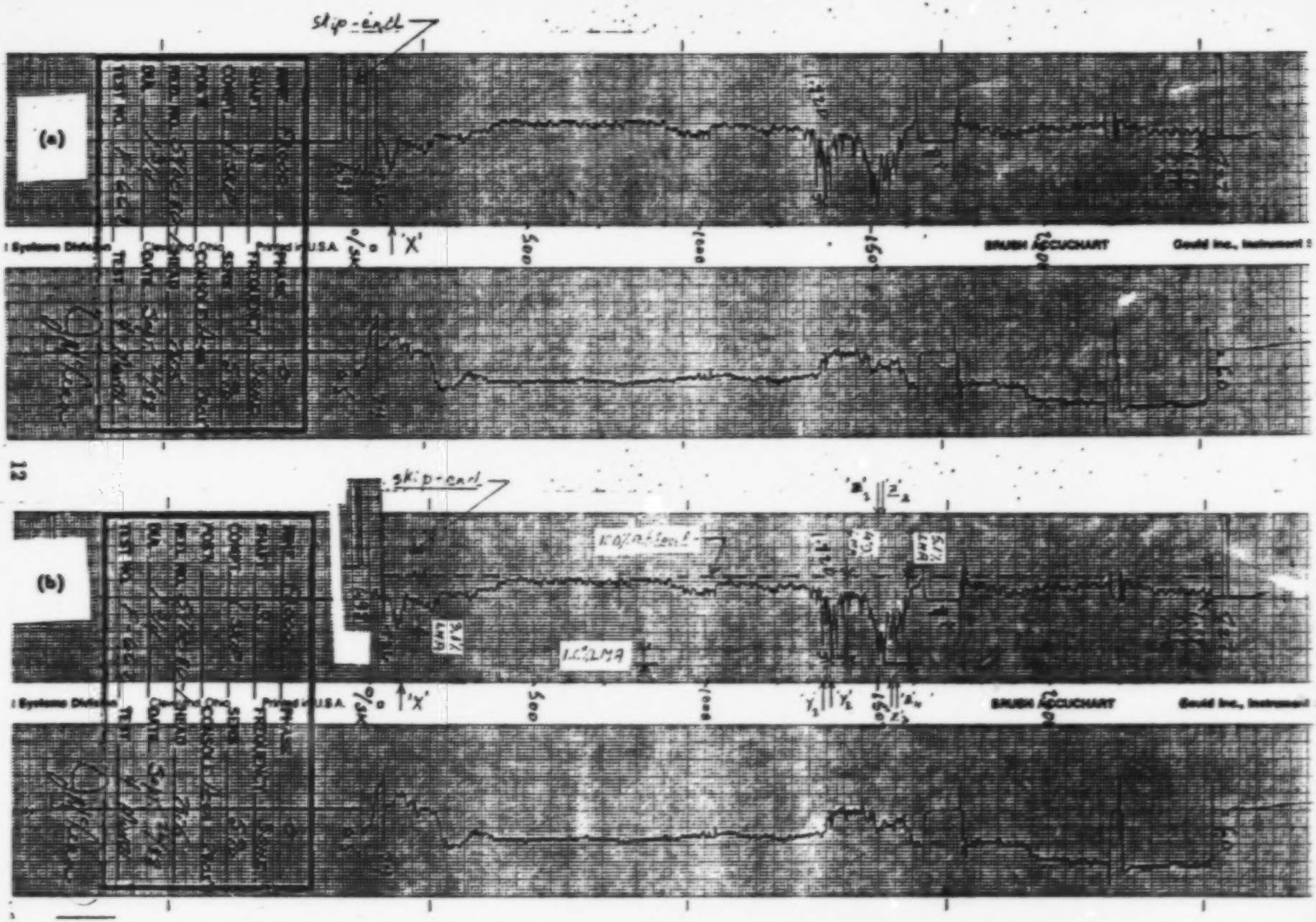


Fig. 1 — Rotesco AC in-situ test of 1988 09 26; (a) as reported, (b) as marked by authors

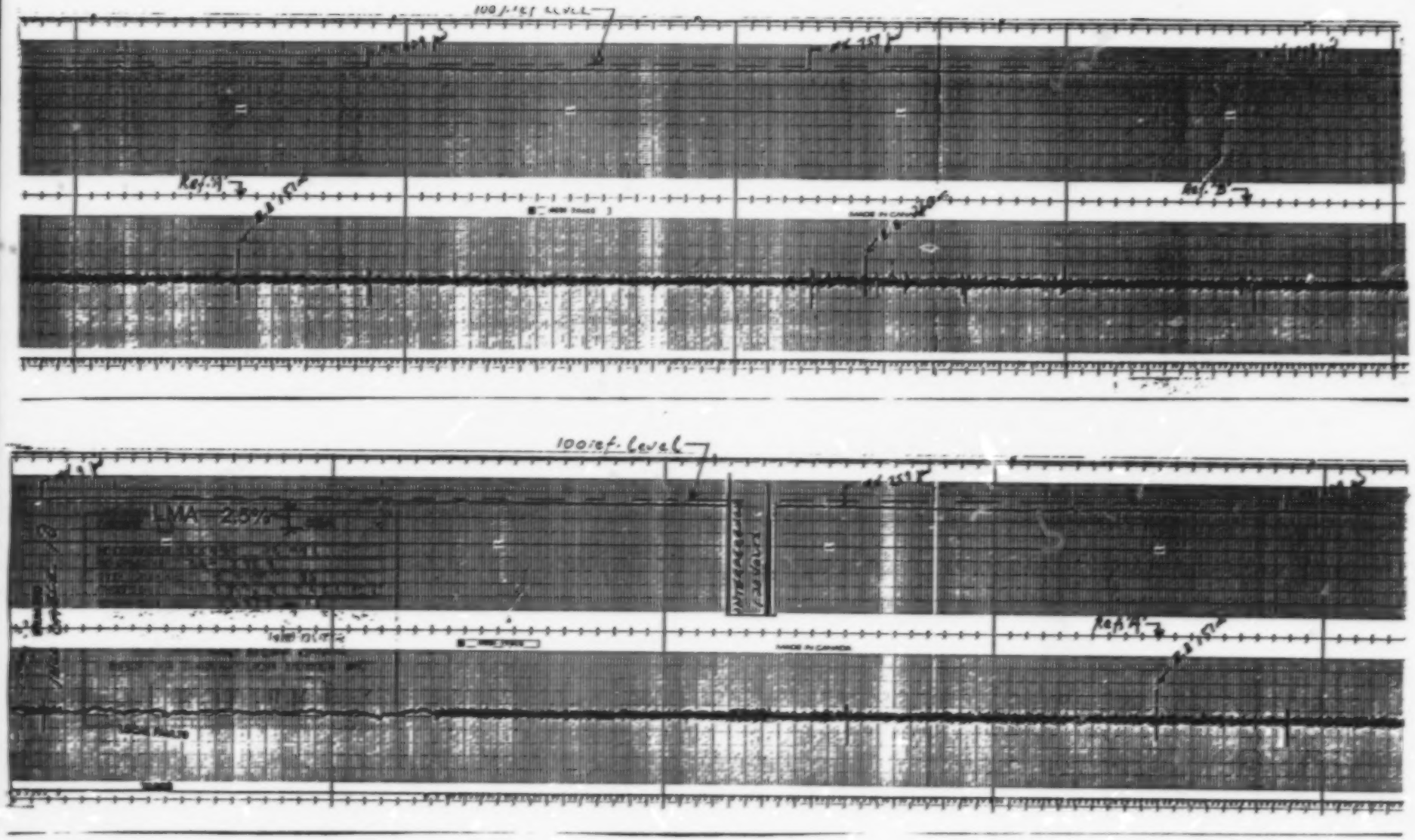


Fig. 2 — Magnograph shop-floor test of 1969 04 04

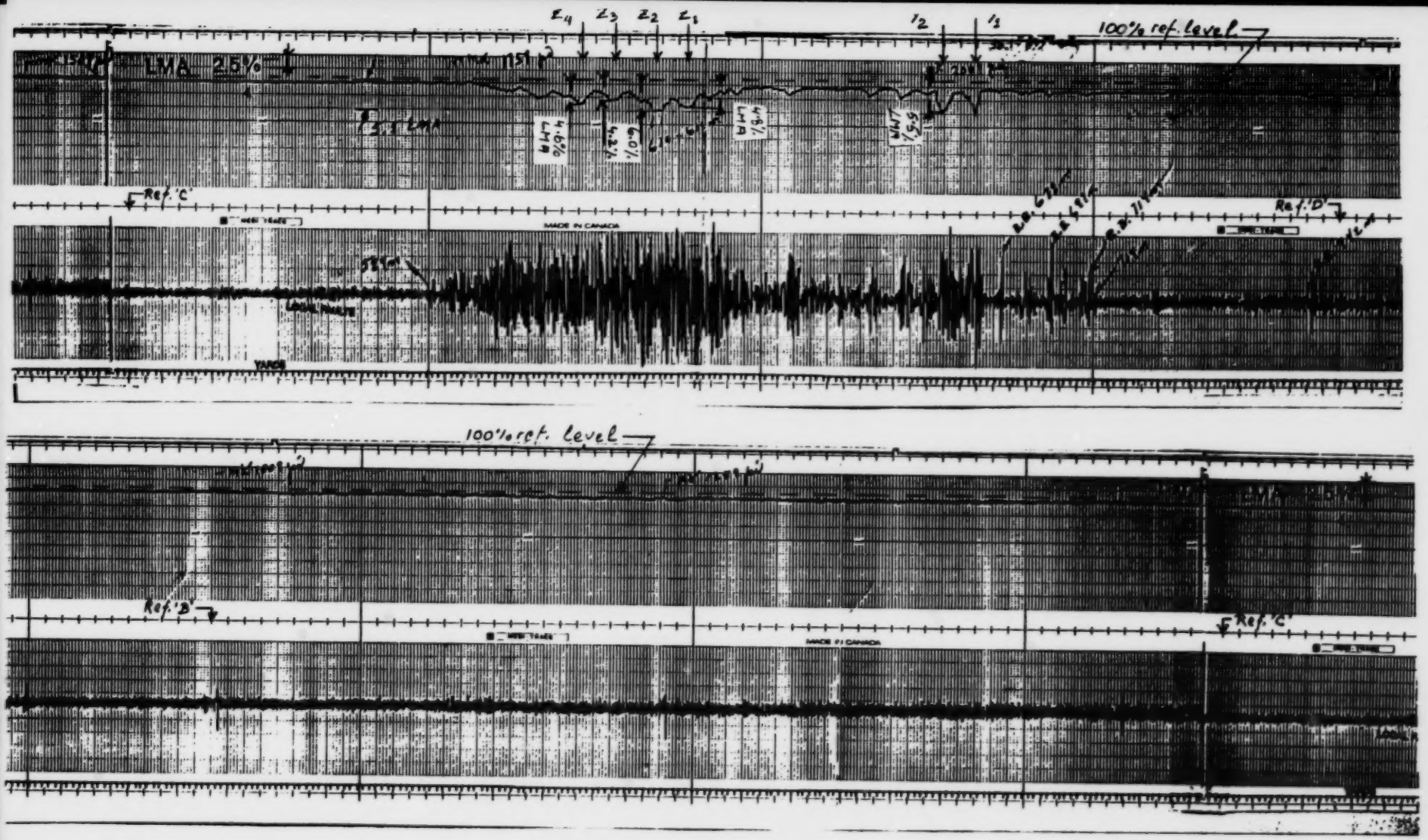


Fig. 2 (continued)— Magnograph shop-floor test of 1989 04 04

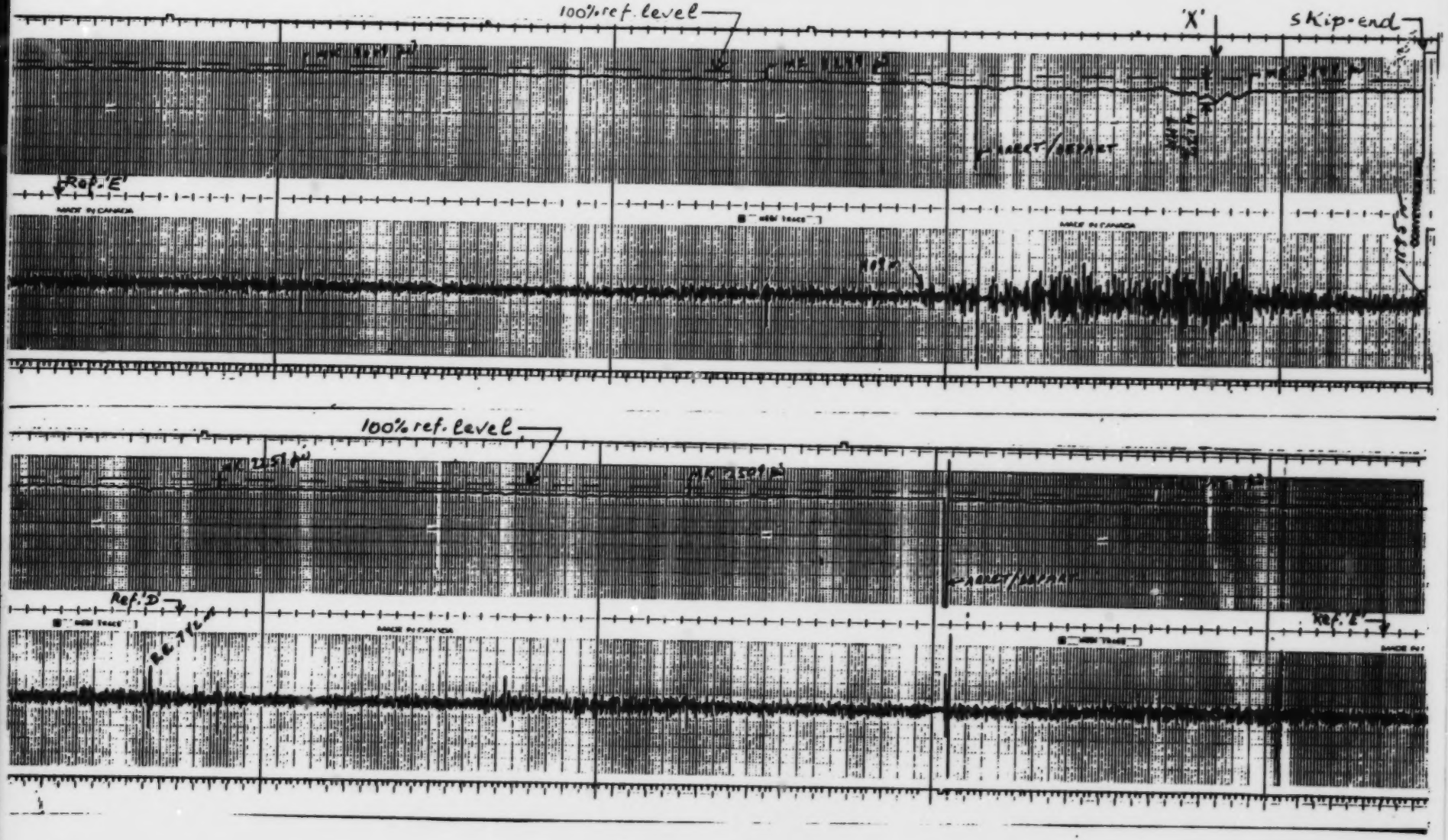


Fig. 2 (continued)— Magnograph shop-floor test of 1989 04 04

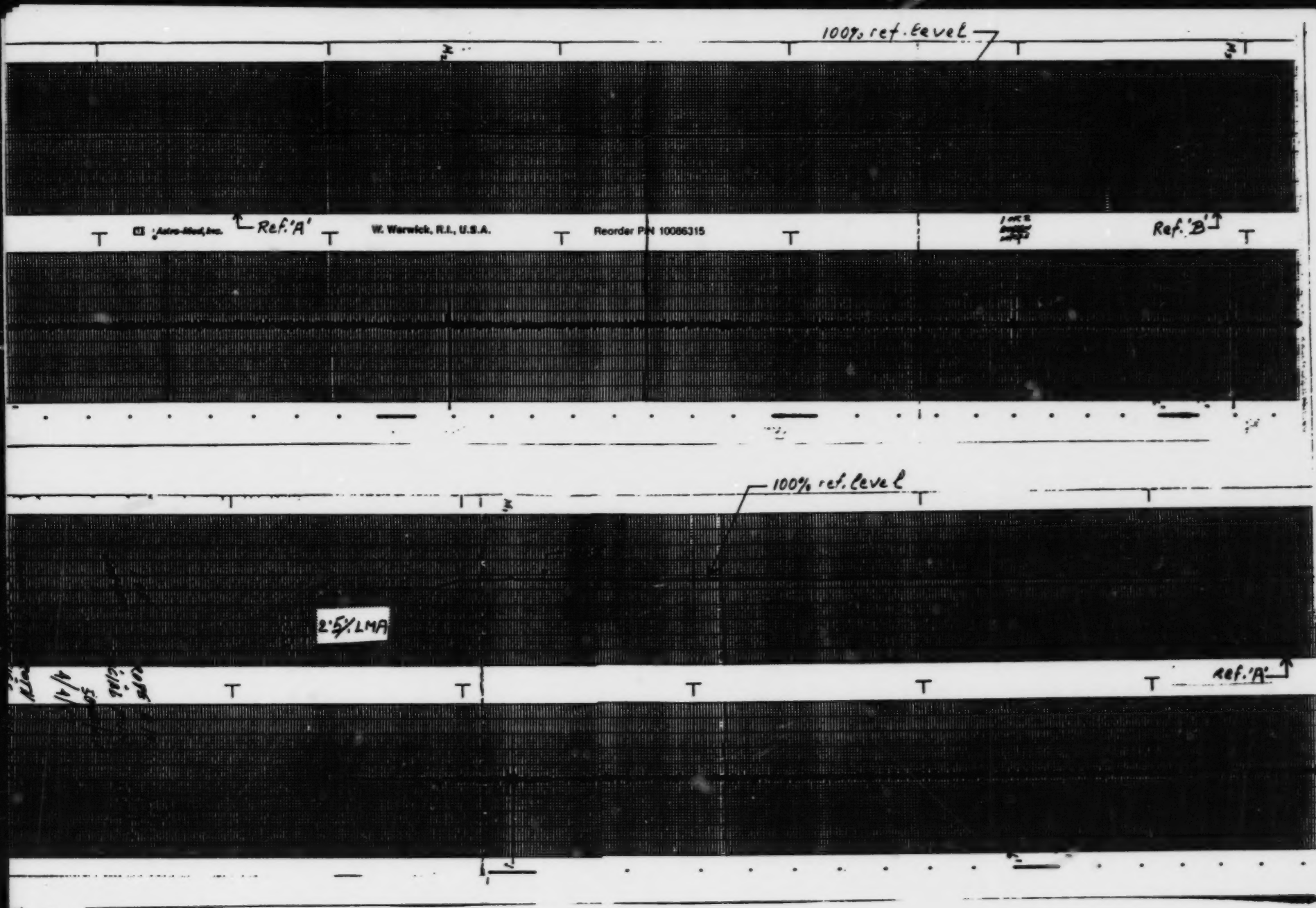
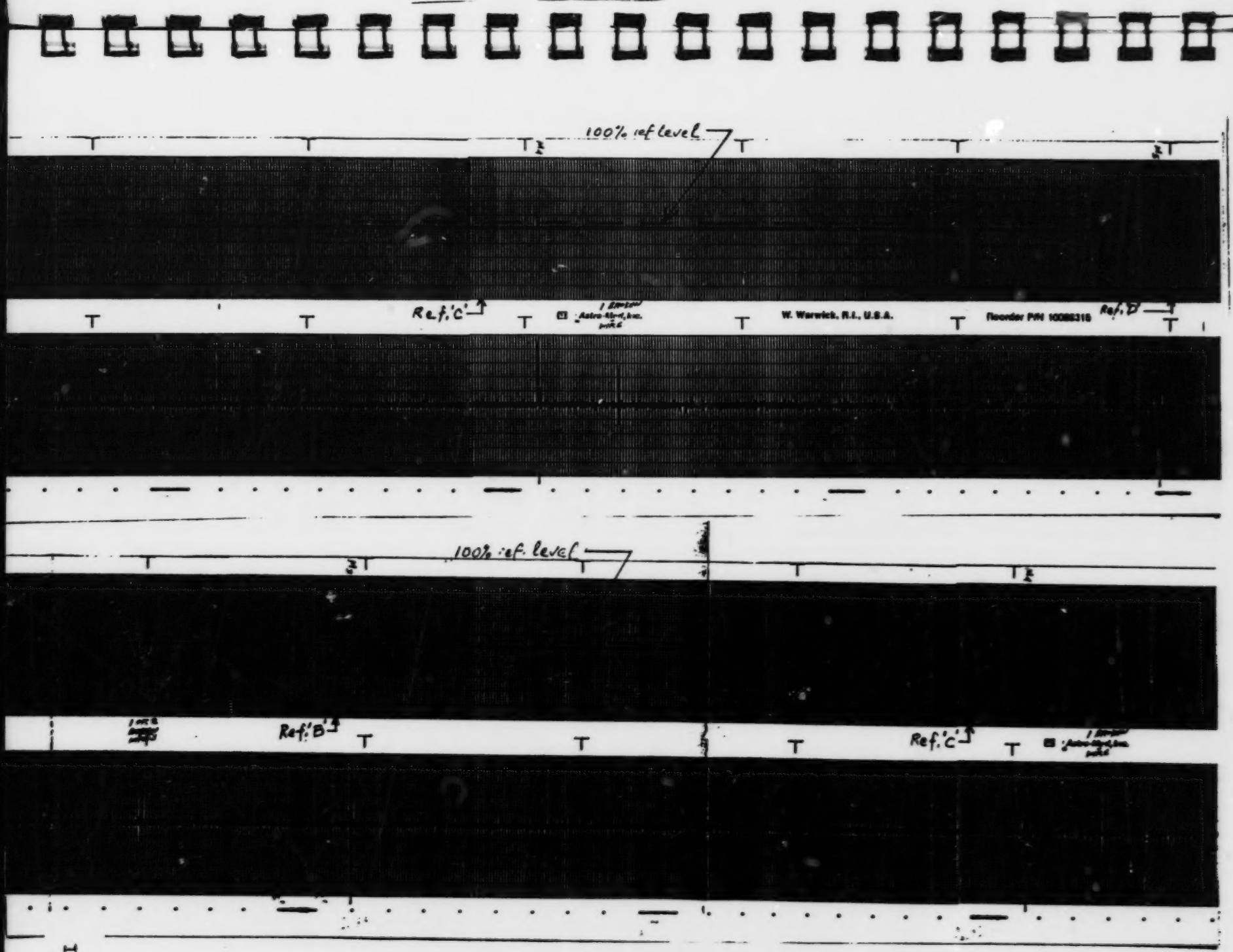


Fig. 3 — LMA-250 shop-floor test of 1989 04 04


100% ref level
Ref. 'C'
W. Warwick, R.I., U.S.A.
Floorder P/N 10085318
Ref. 'D'
100% ref. level
Ref. 'B'
Ref. 'C'

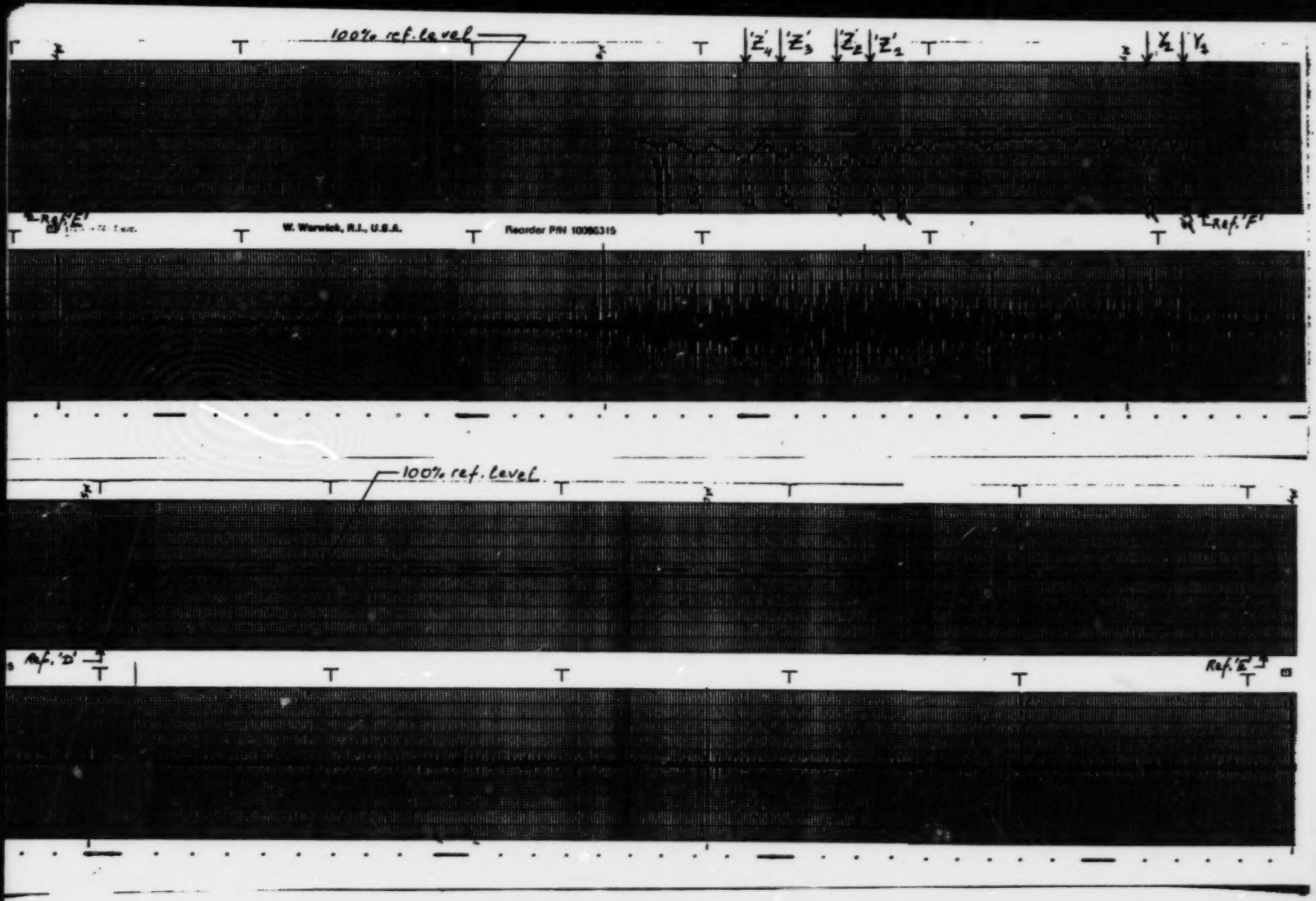


Fig. 3 (continued) — LMA-250 shop-floor test of 1989 04 04

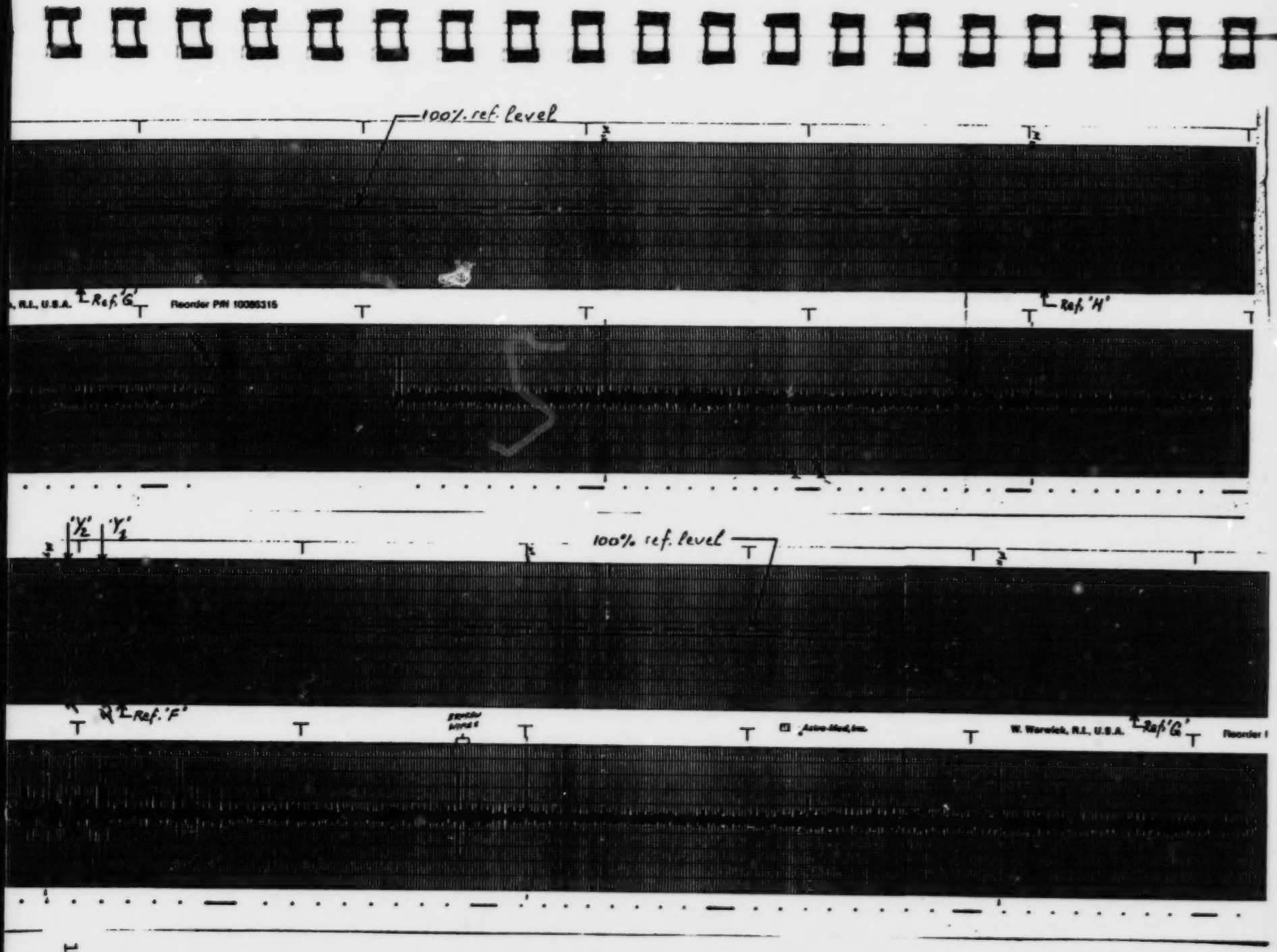


Fig. 3 (continued) — LMA-250 shop-floor test of 1989 04 04

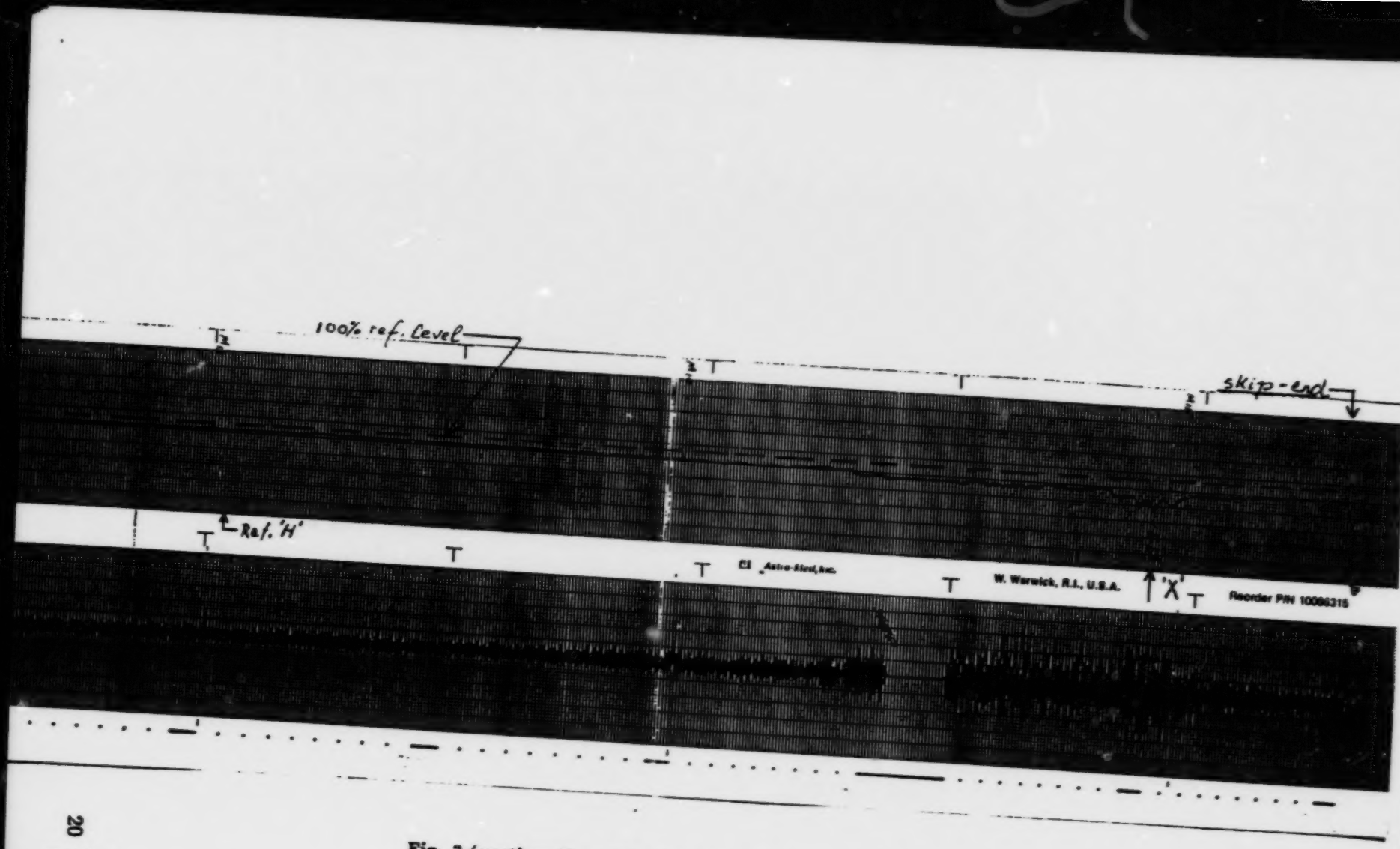


Fig. 3 (continued) — LMA-250 shop-floor test of 1989 04 04

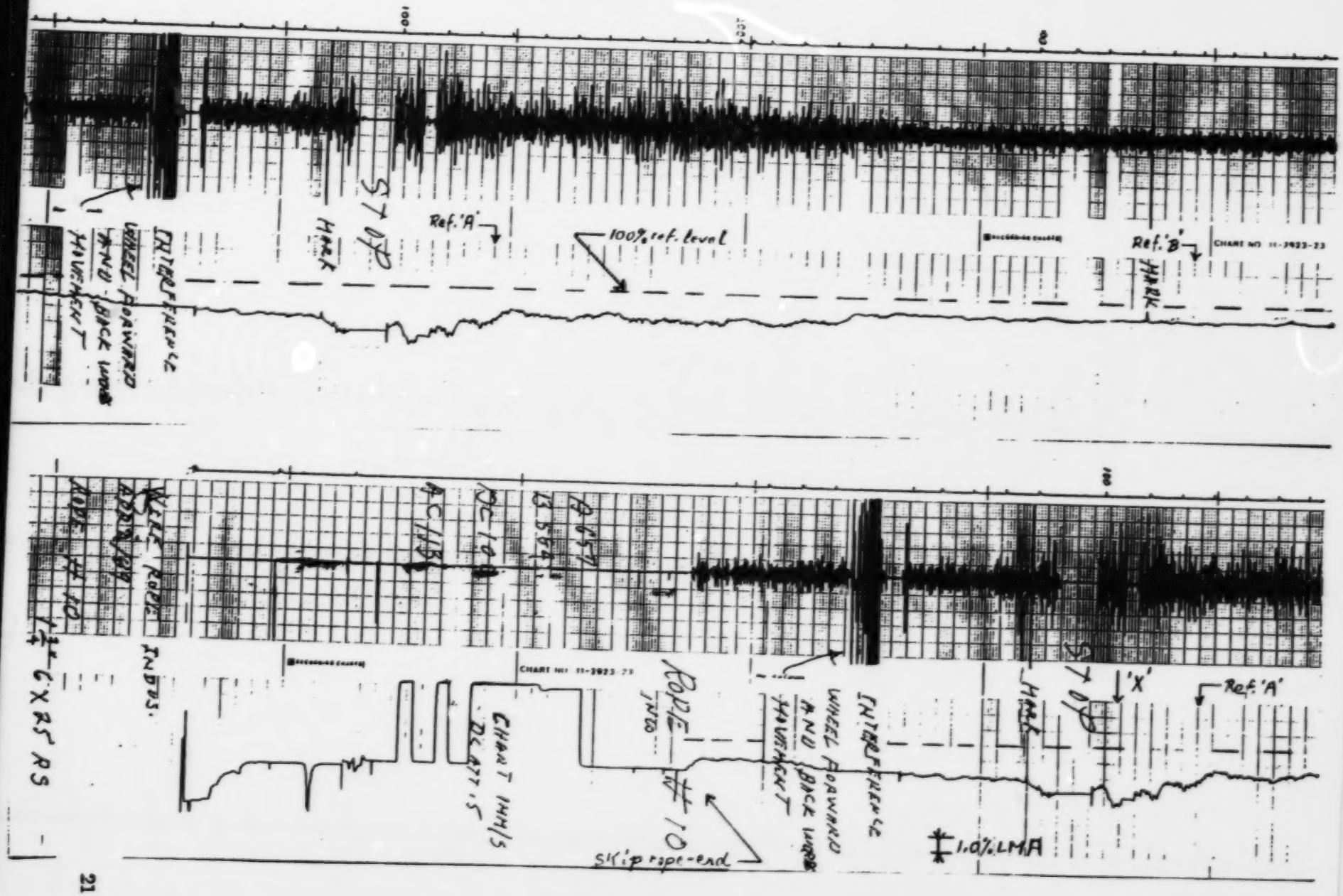


Fig. 4a — Rotescograph shop-floor test of 1989 04 04

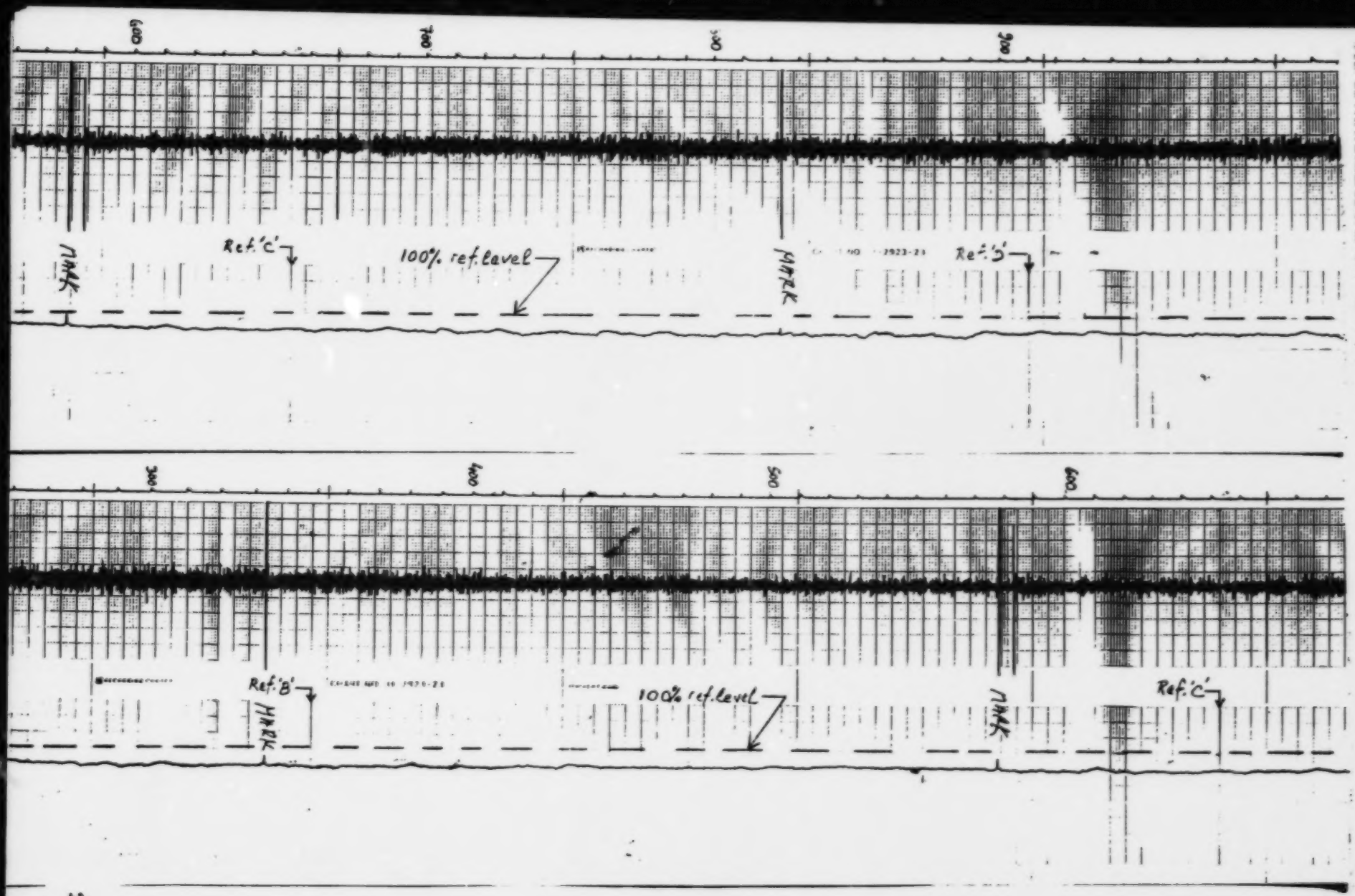


Fig. 4a (continued) — Rotescograph shop-floor test of 1989 04 04

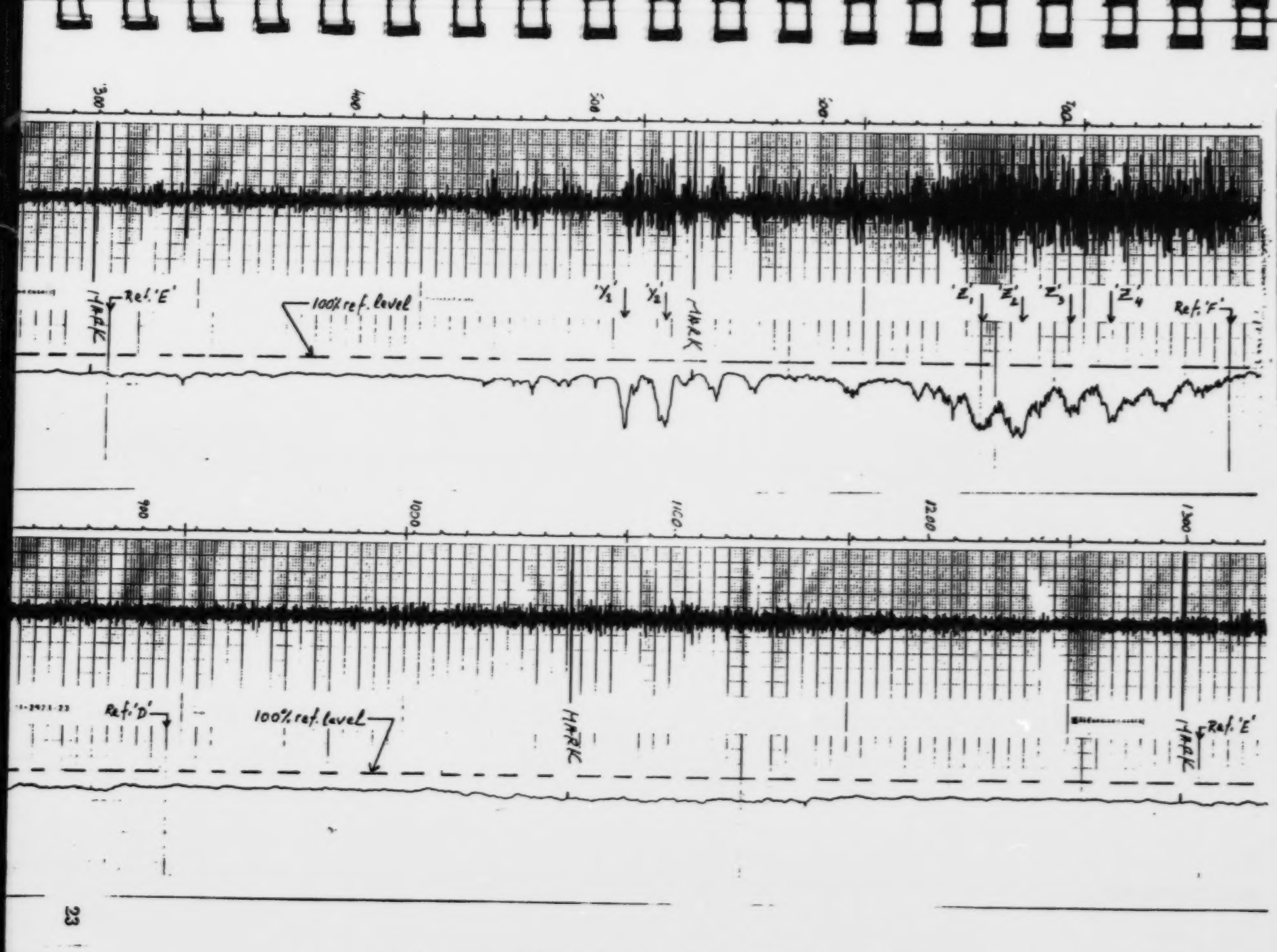


Fig. 4a (continued) — Rotescograph shop-floor test of 1989 04 04

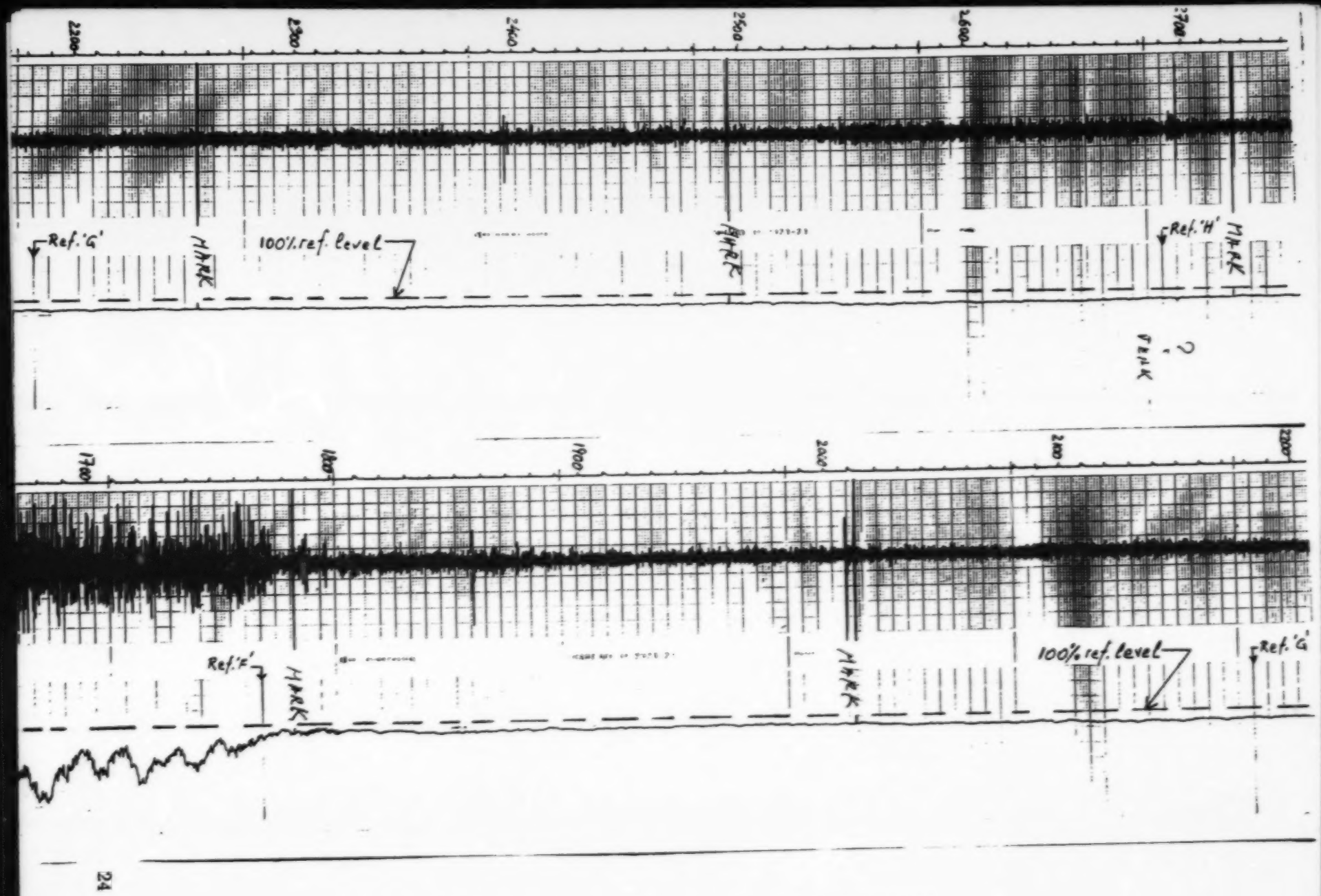


Fig. 4a (continued) — Rotescograph shop-floor test of 1989 04 04

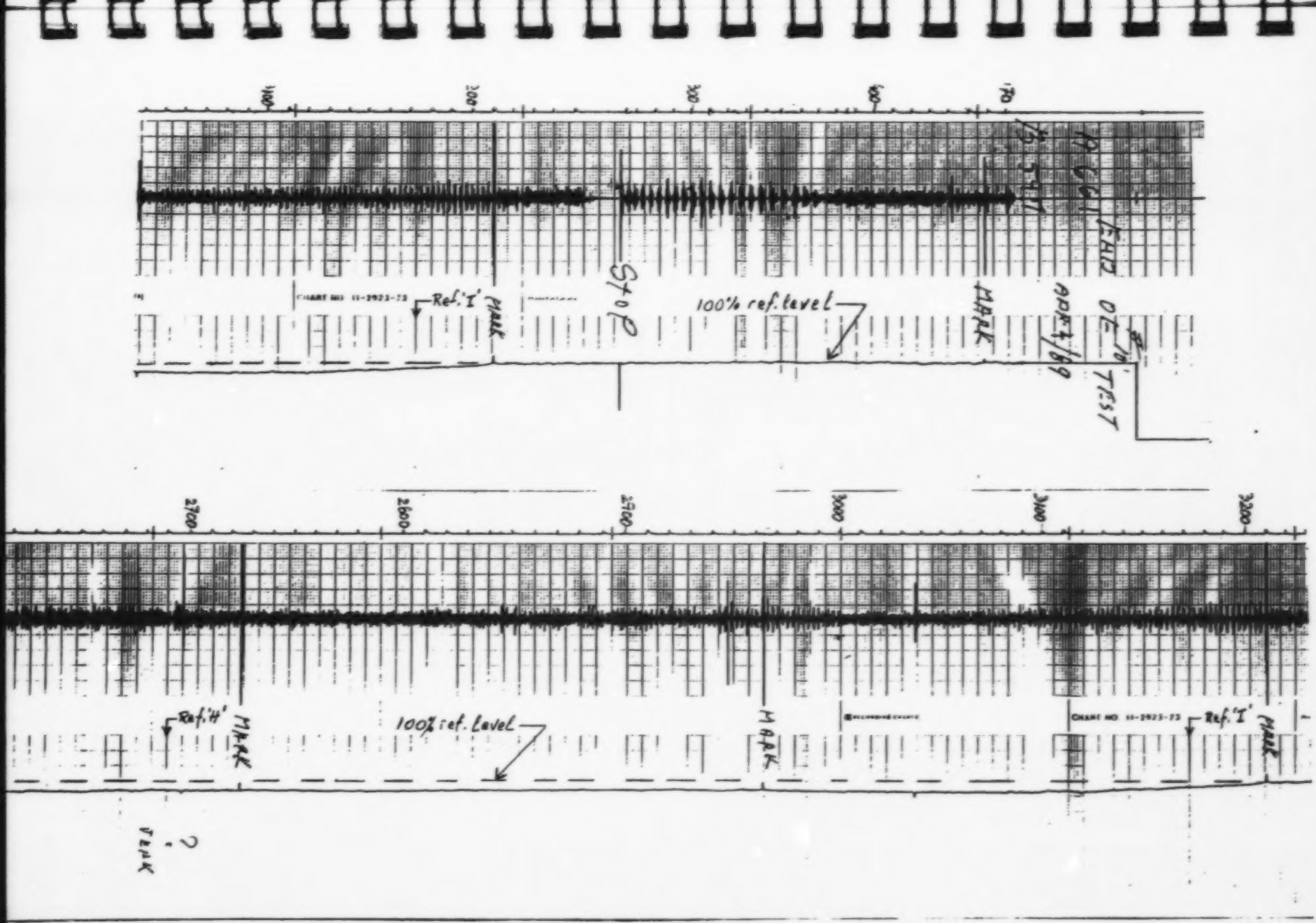


Fig. 4a (continued) — Rotescograph shop-floor test of 1989 04 04

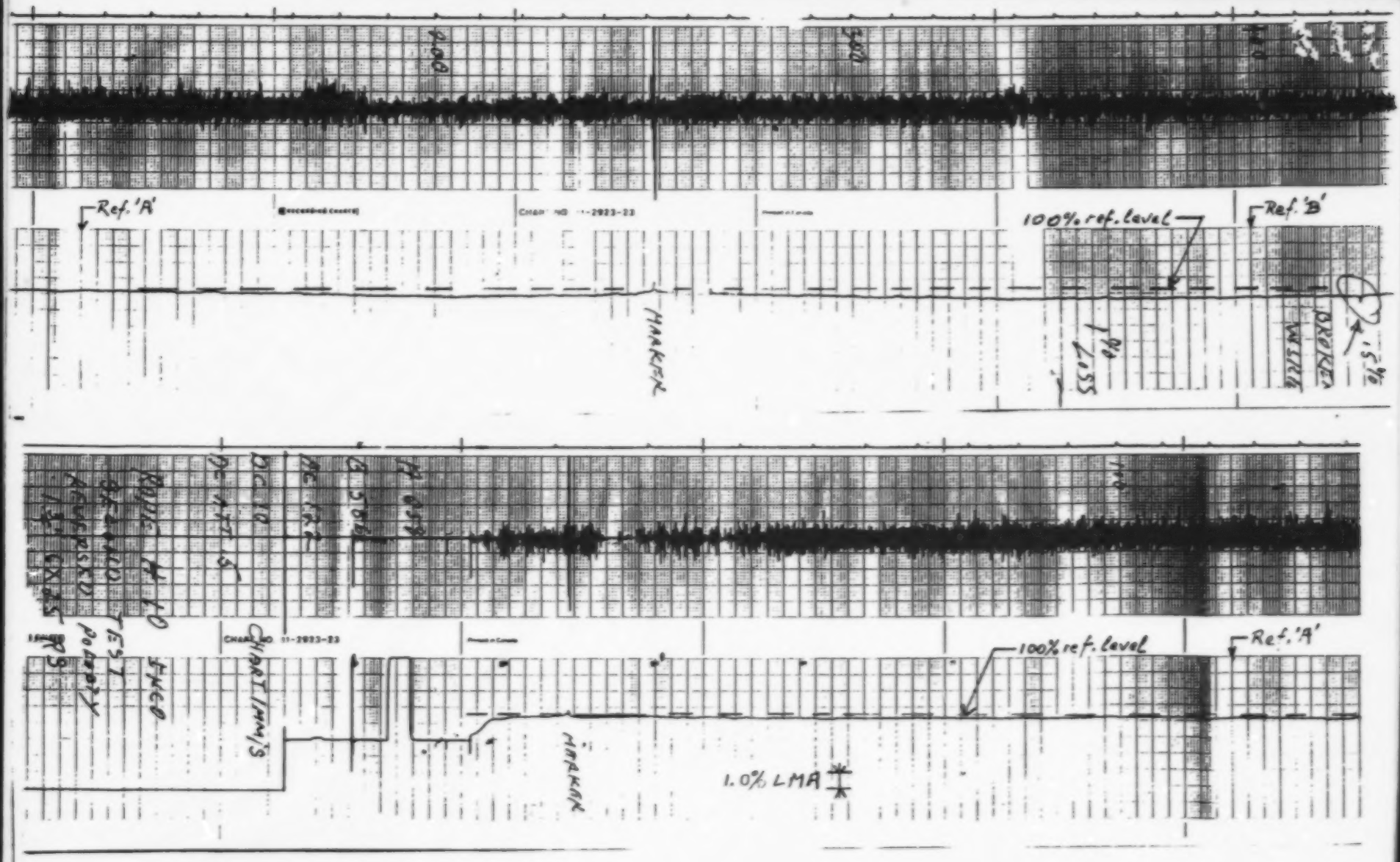


Fig. 4b — Rotescograph shop-floor test of 1989 04 10

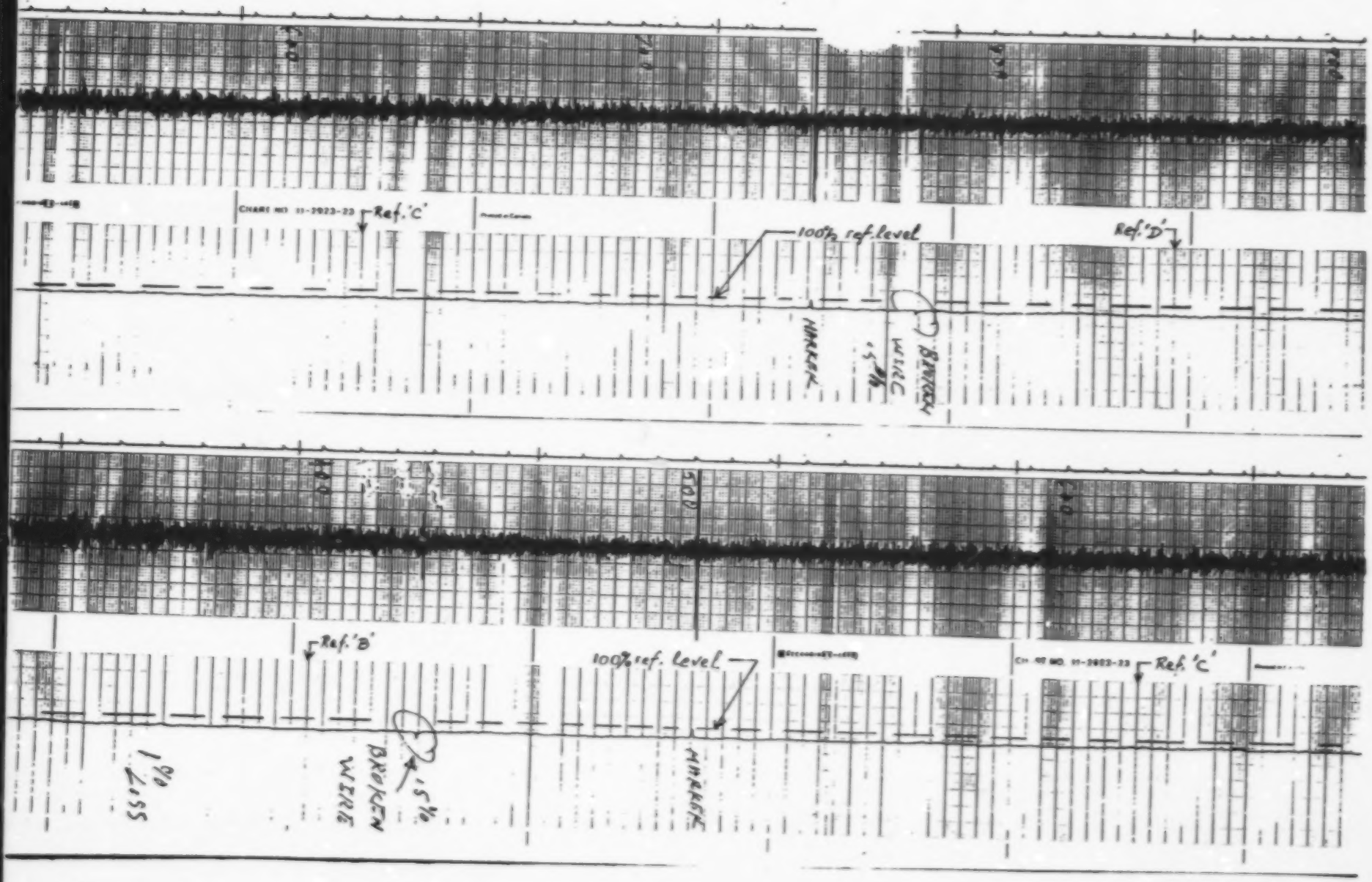


Fig. 4b (continued) — Rotescograph shop-floor test of 1989 04 10

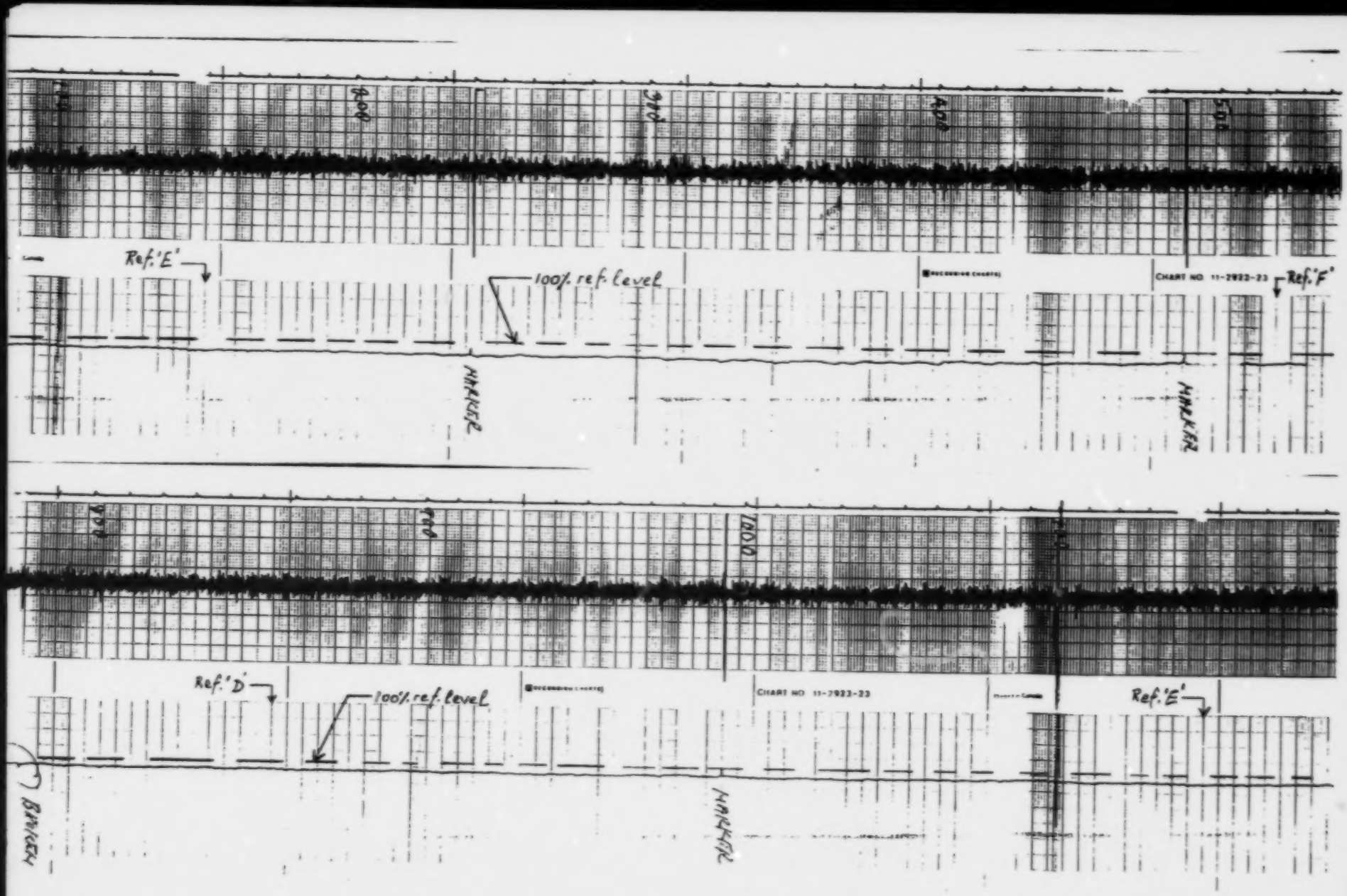


Fig. 4b (continued) — Rotescograph shop-floor test of 1989 04 10

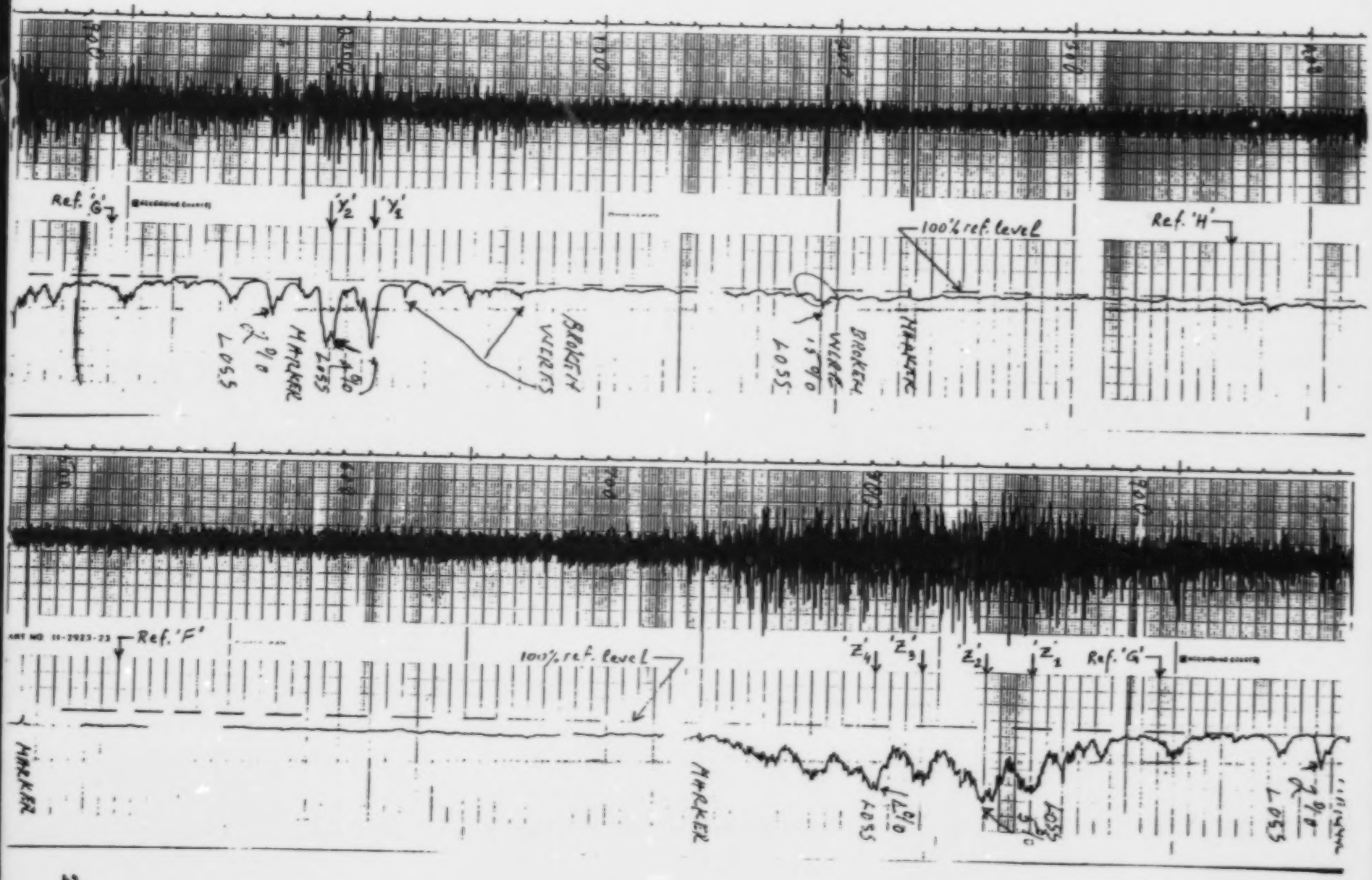


Fig. 4b (continued) — Rotescograph shop-floor test of 1989 04 10

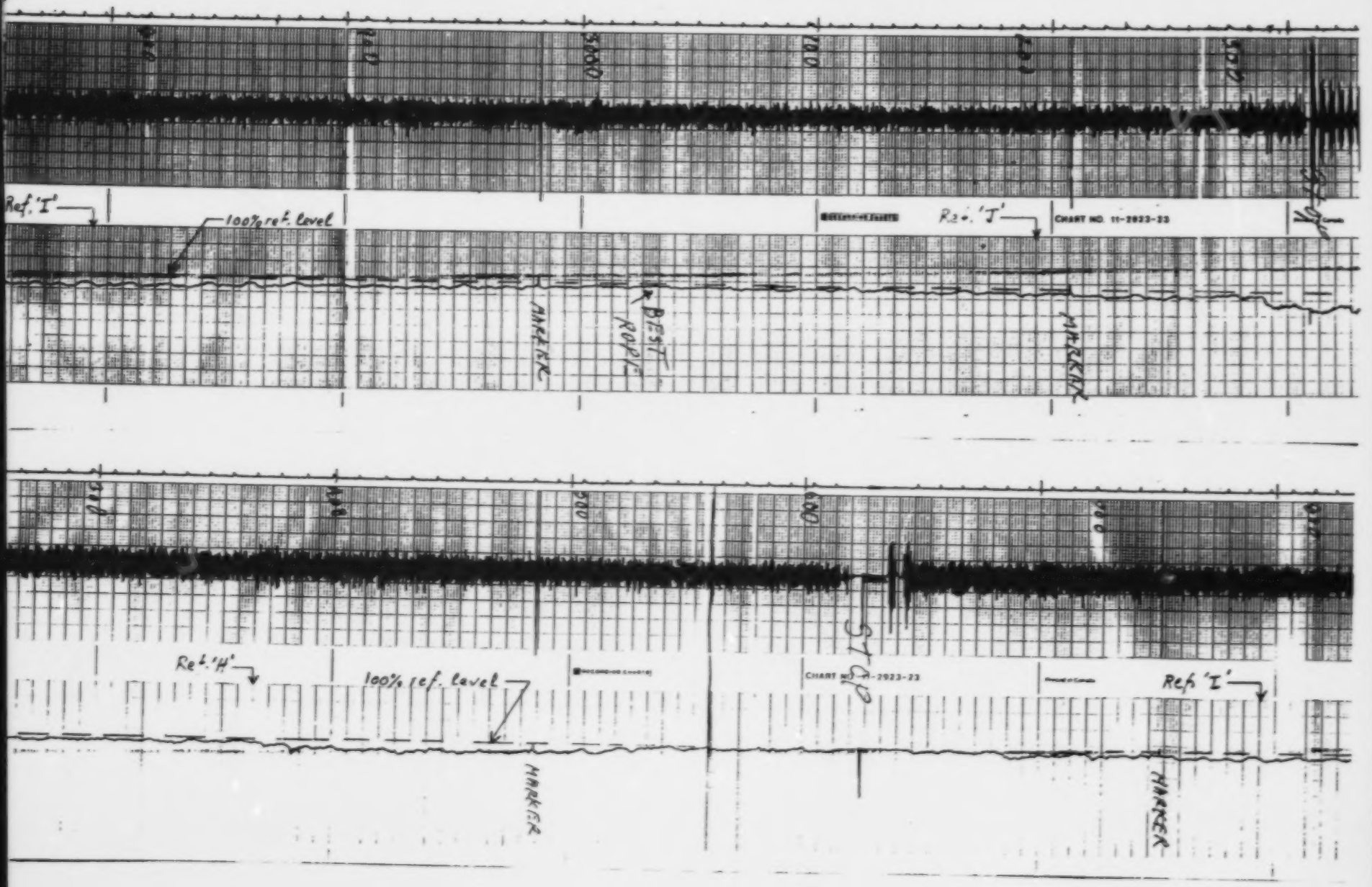


Fig. 4b (continued) — Rotescograph shop-floor test of 1989 04 10

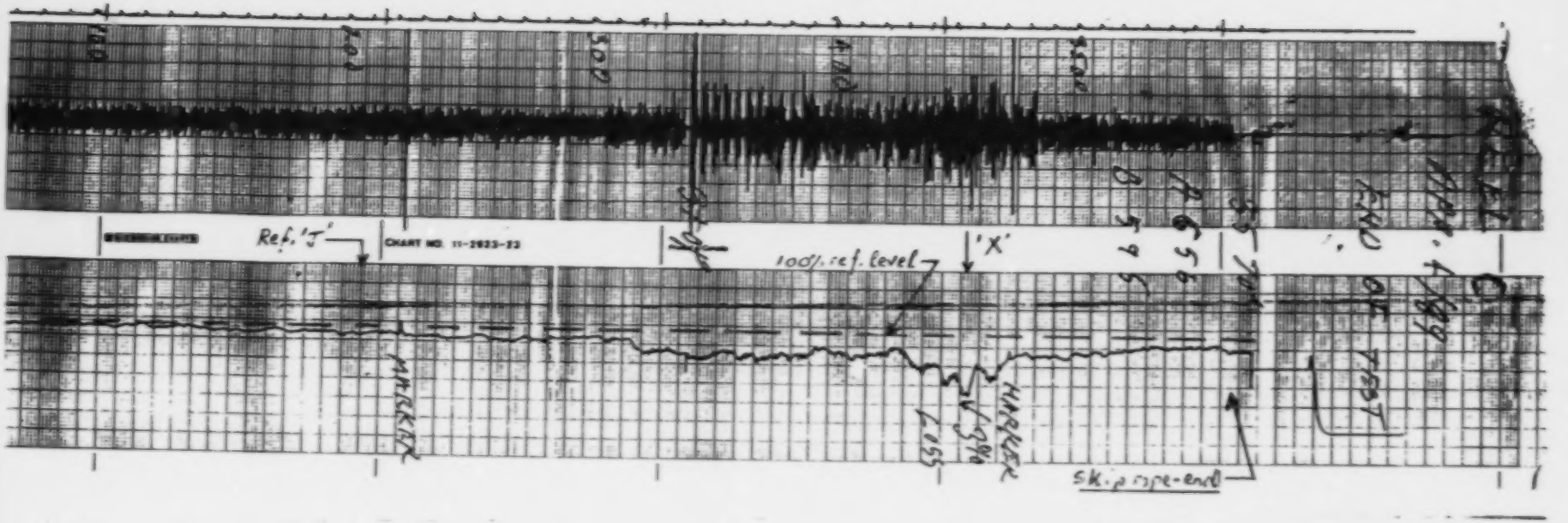


Fig. 4b (continued) — Rotescograph shop-floor test of 1989 04 10

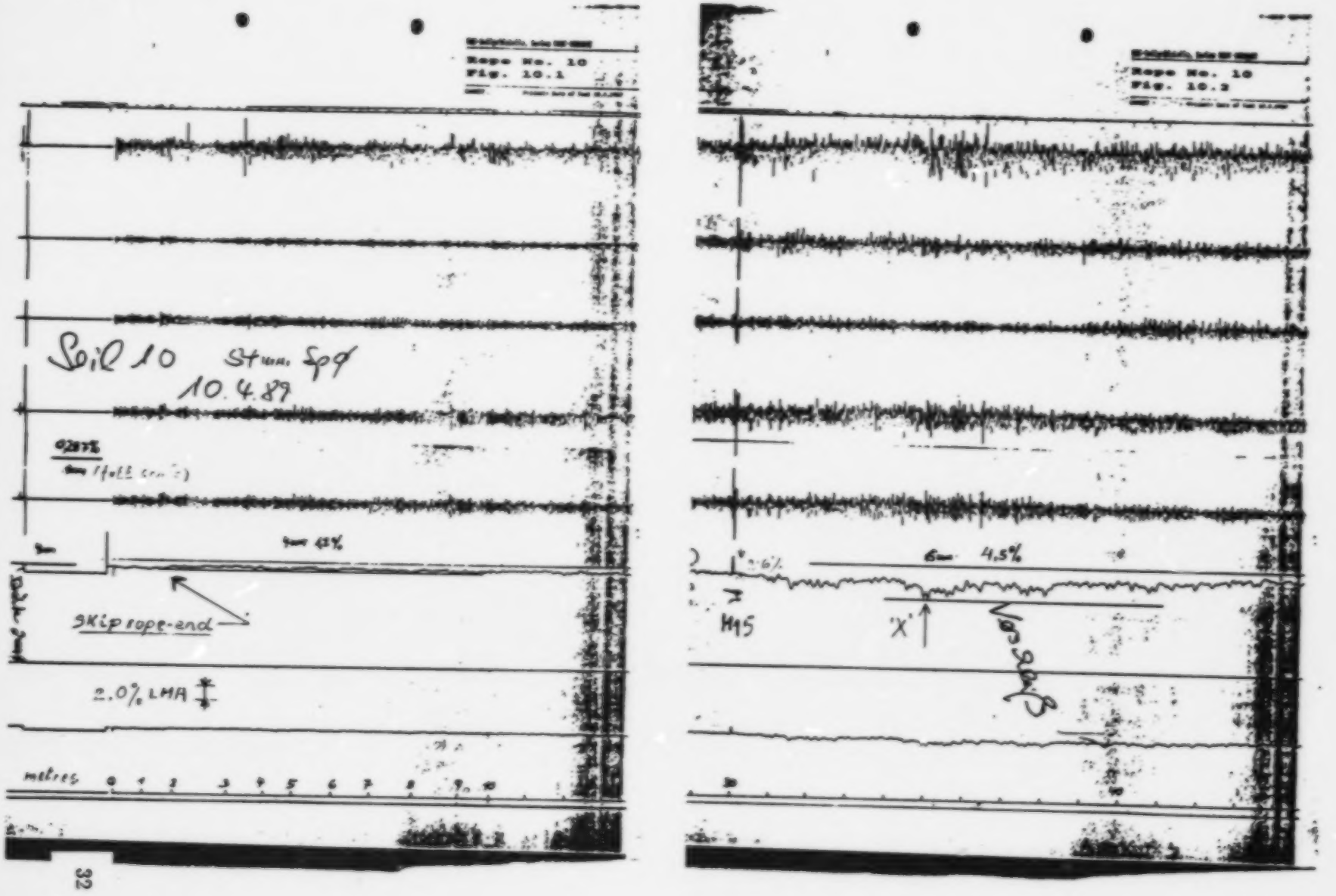
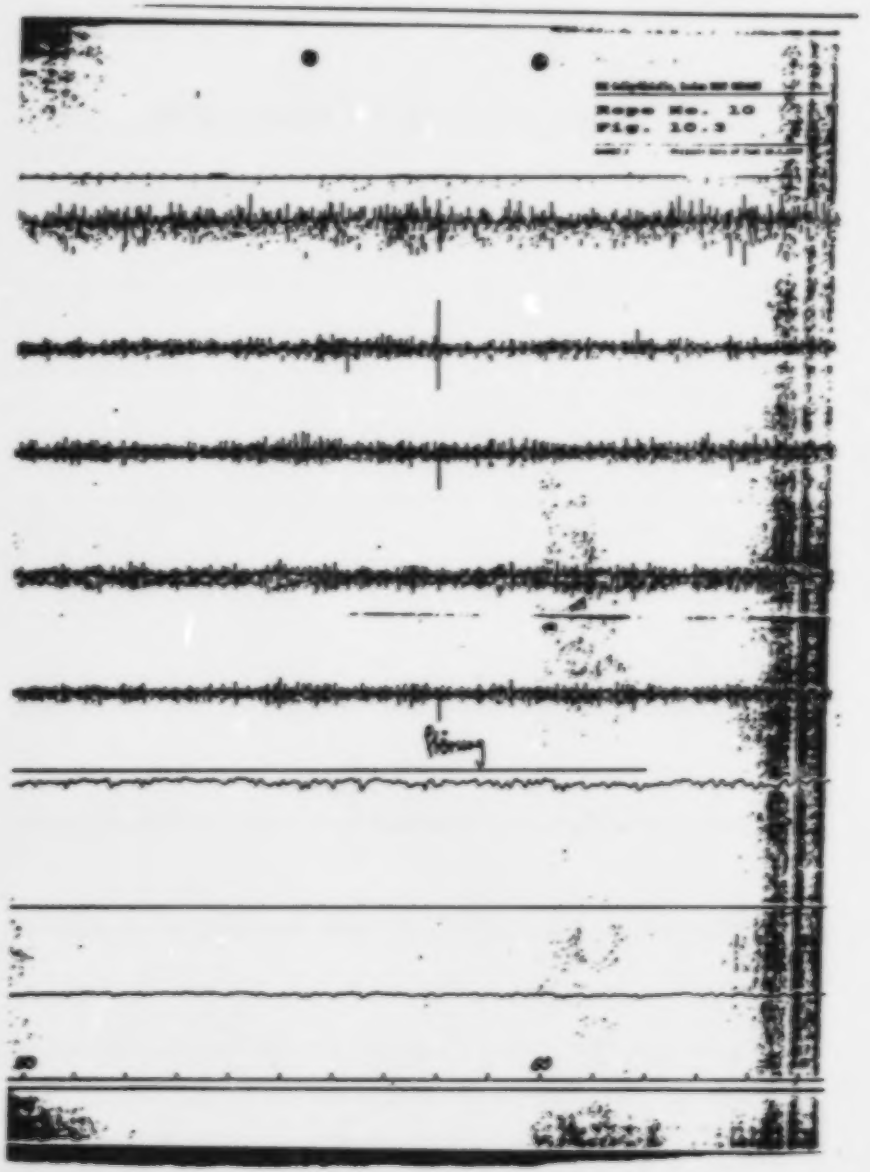


Fig. 5 — WBK shop-floor test of 1989 04 10



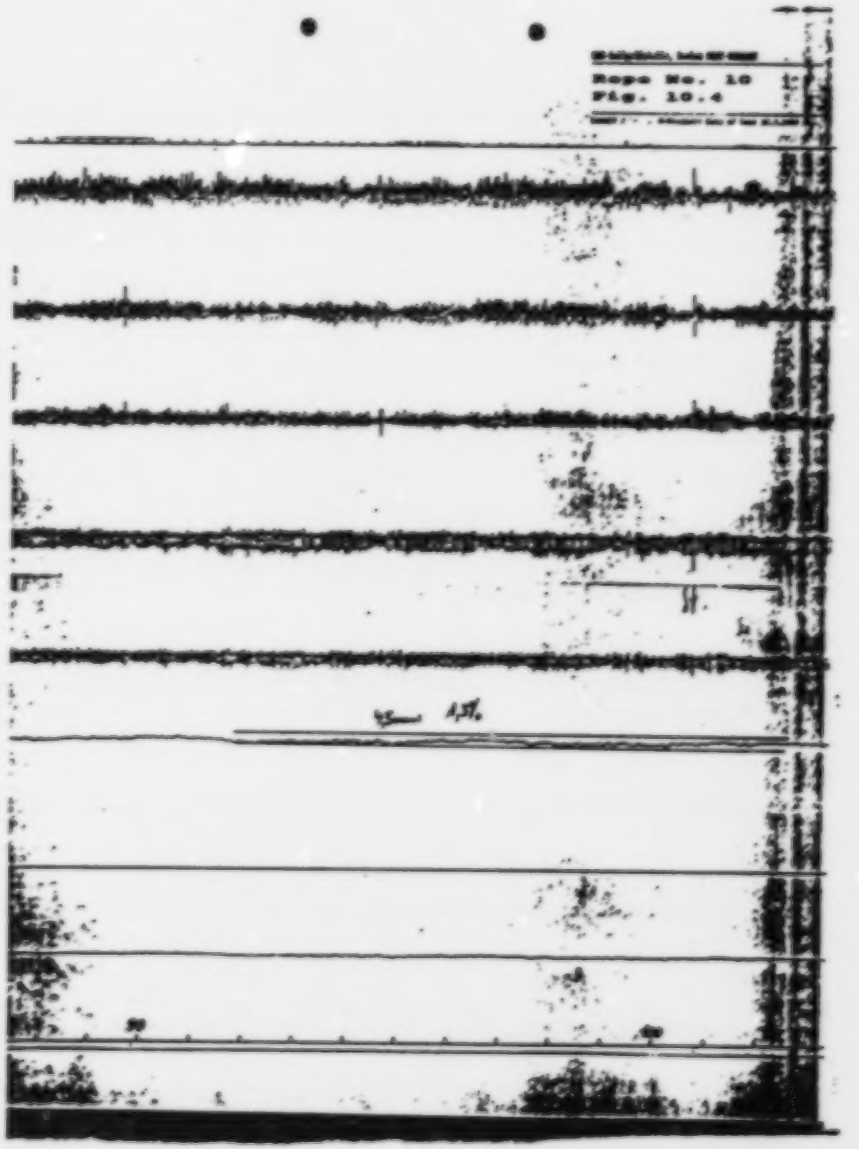


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

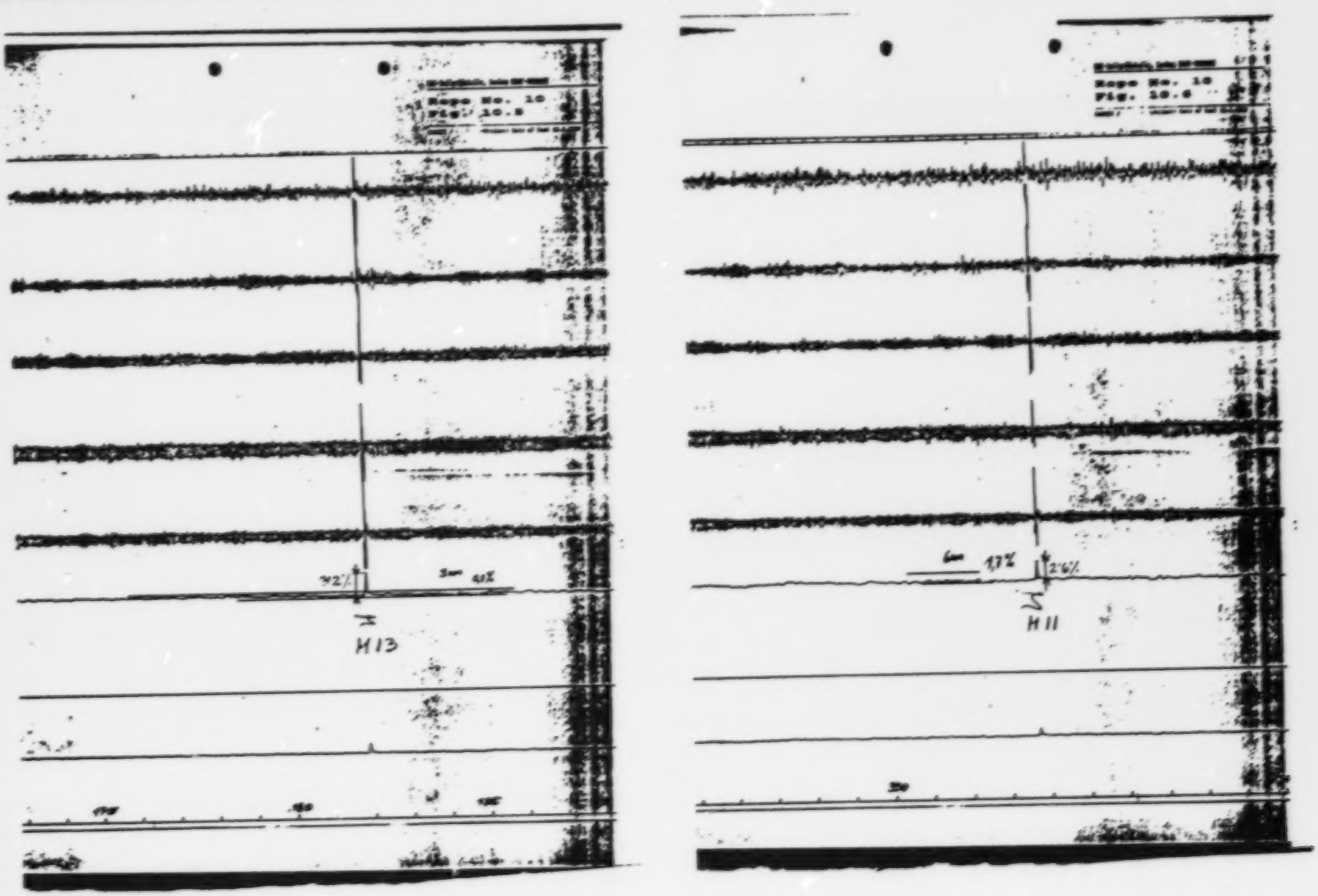
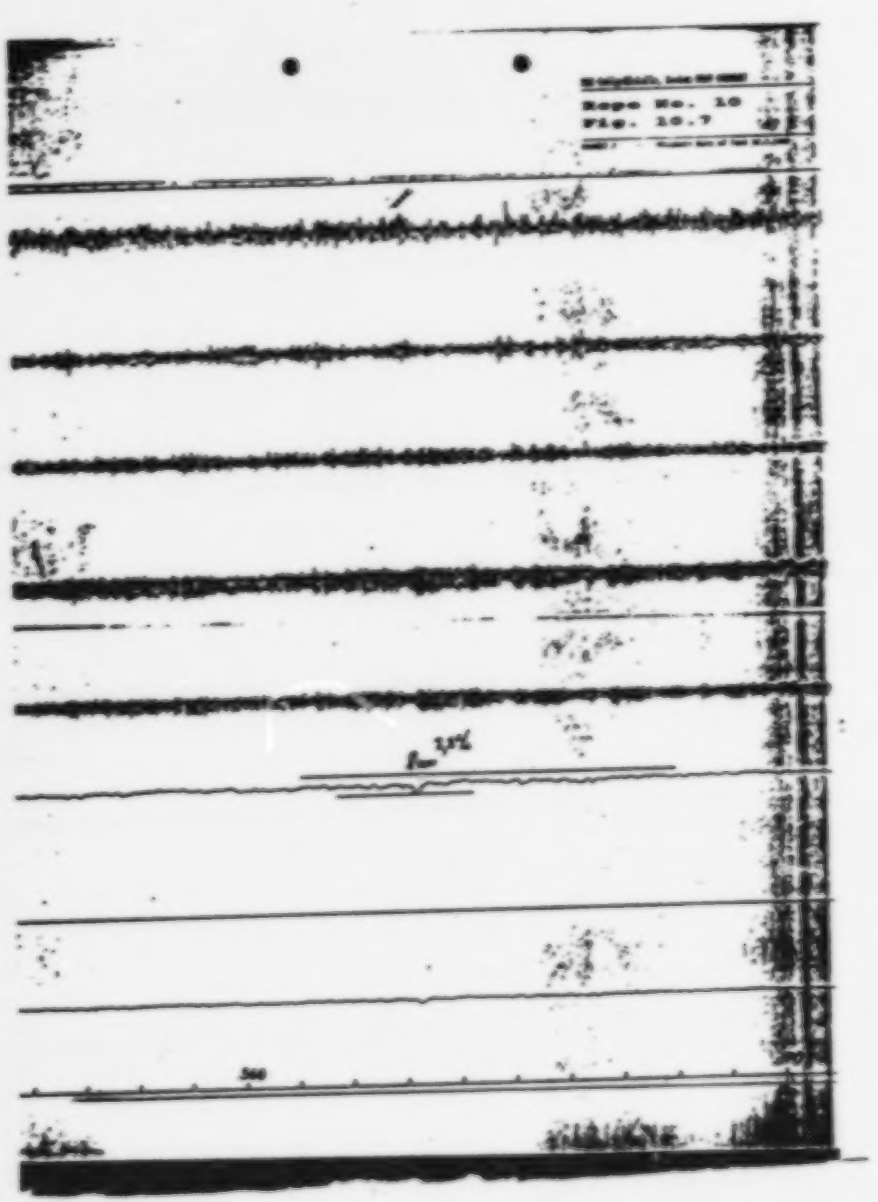


Fig. 5 (continued) — WBK shop-floor test of 1969 04 10



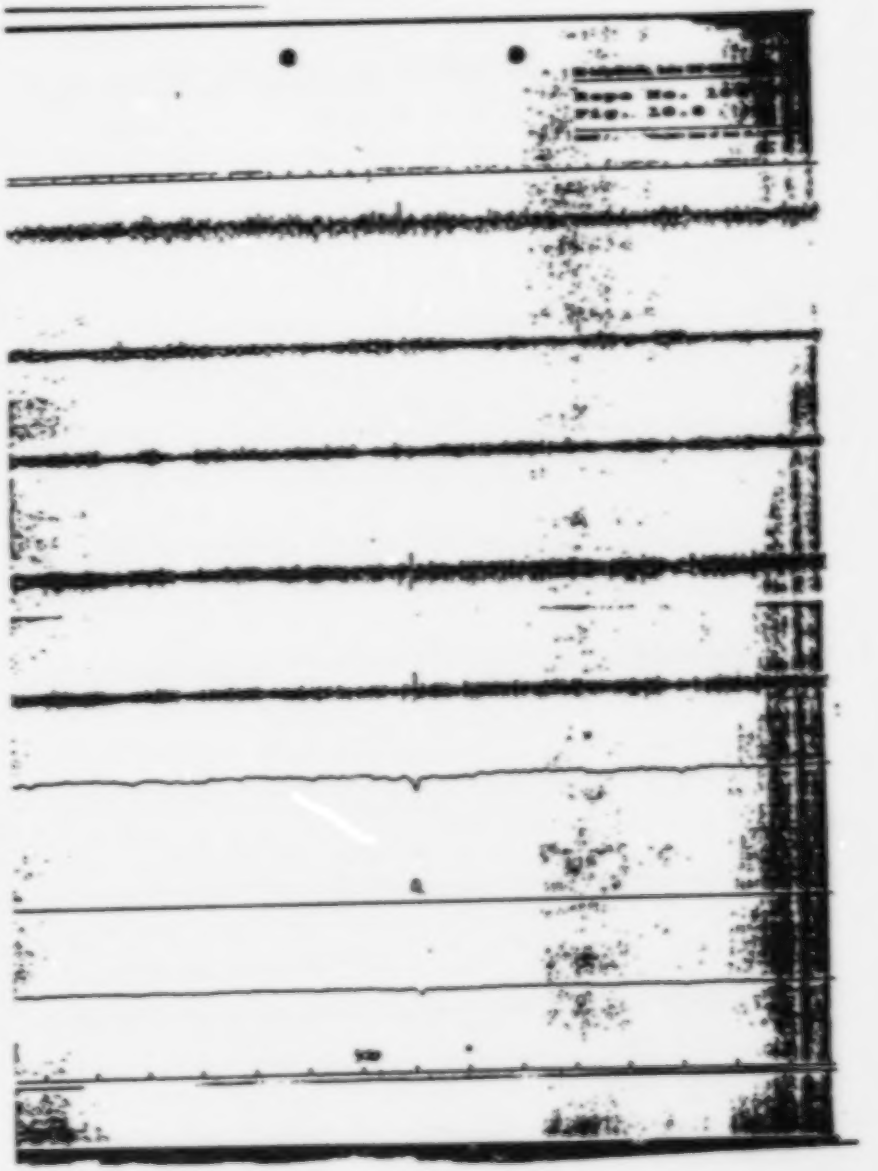


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

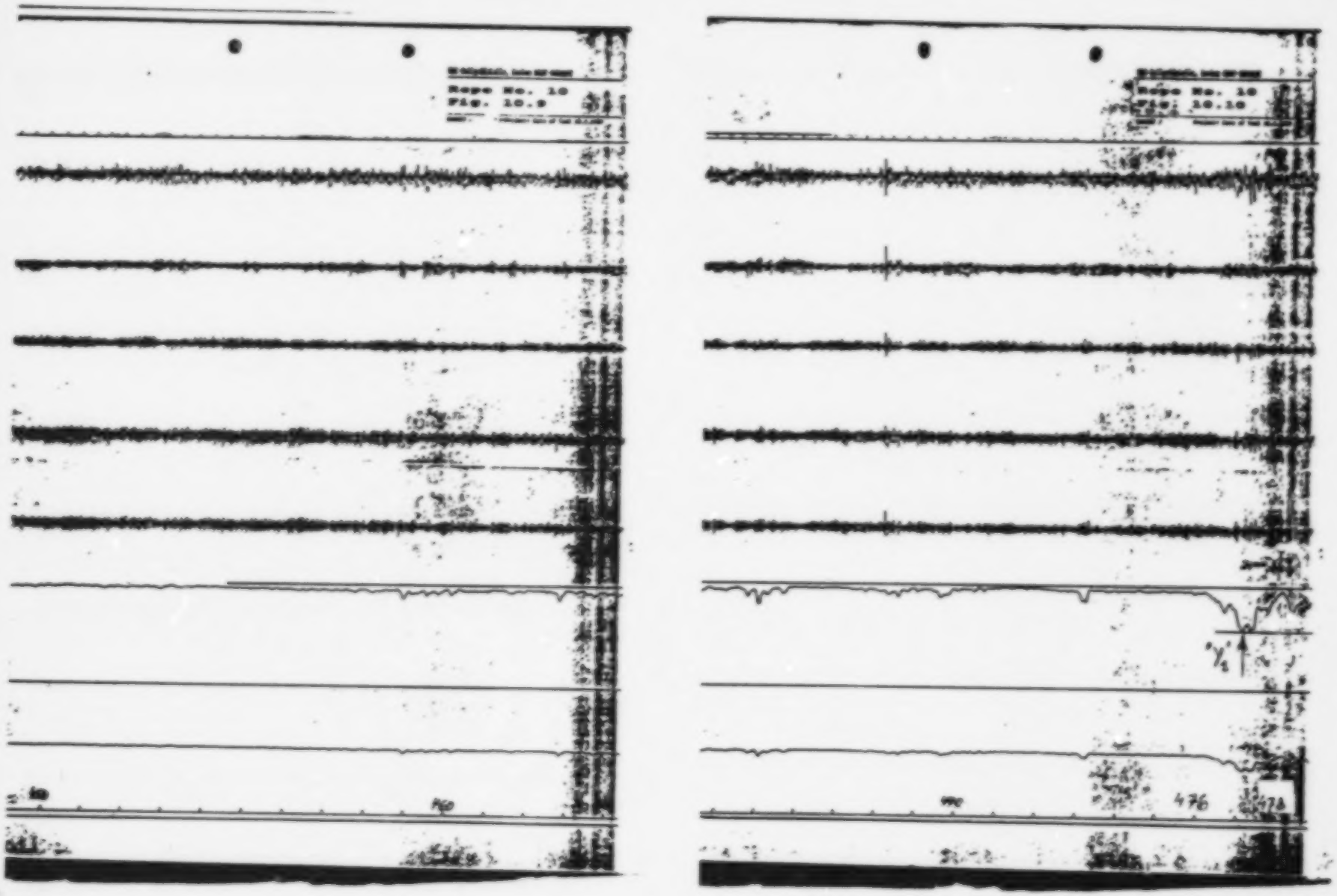


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

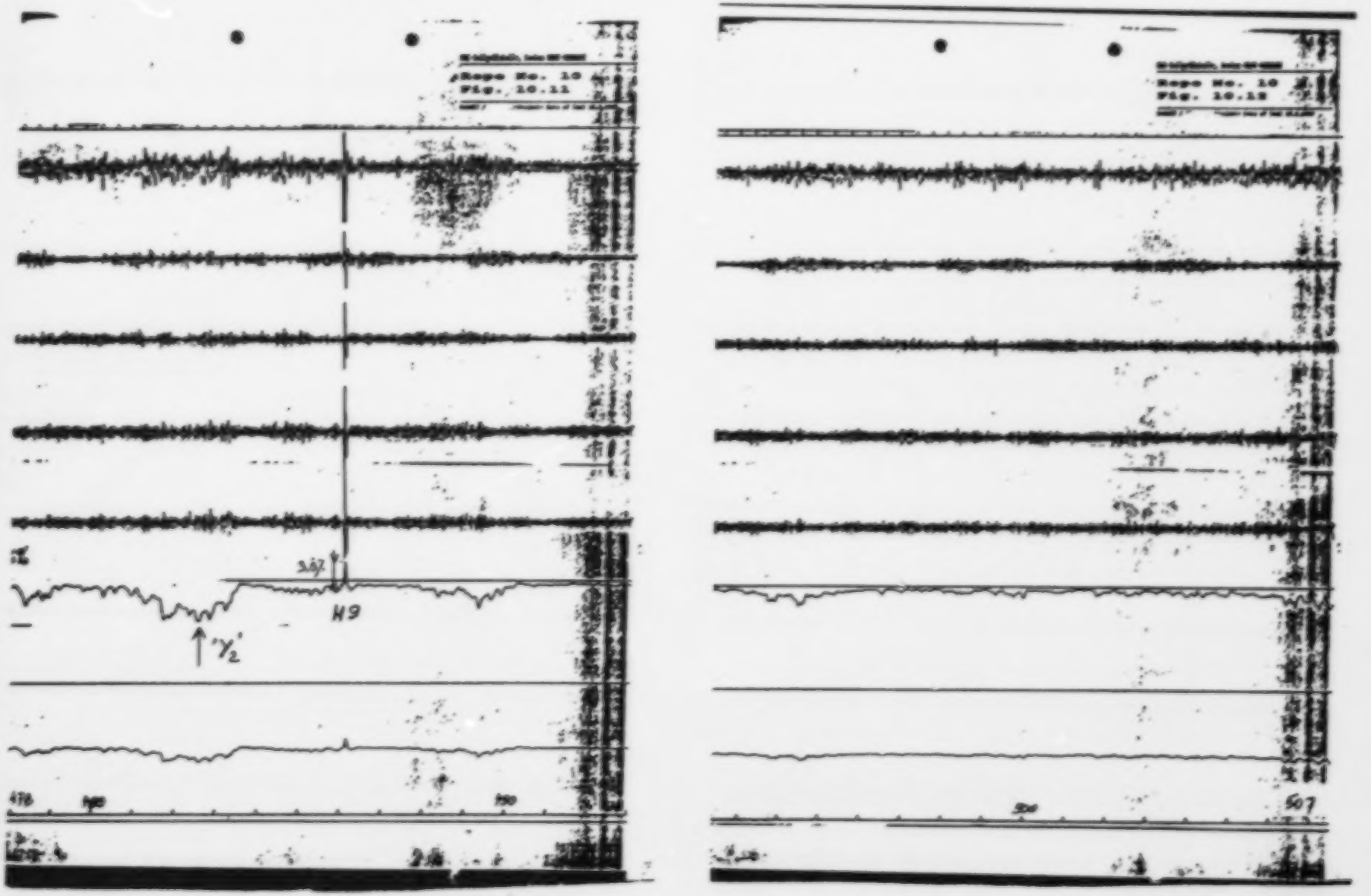


Fig. 5 (continued) — WBK shop-floor test of 1980 04 10

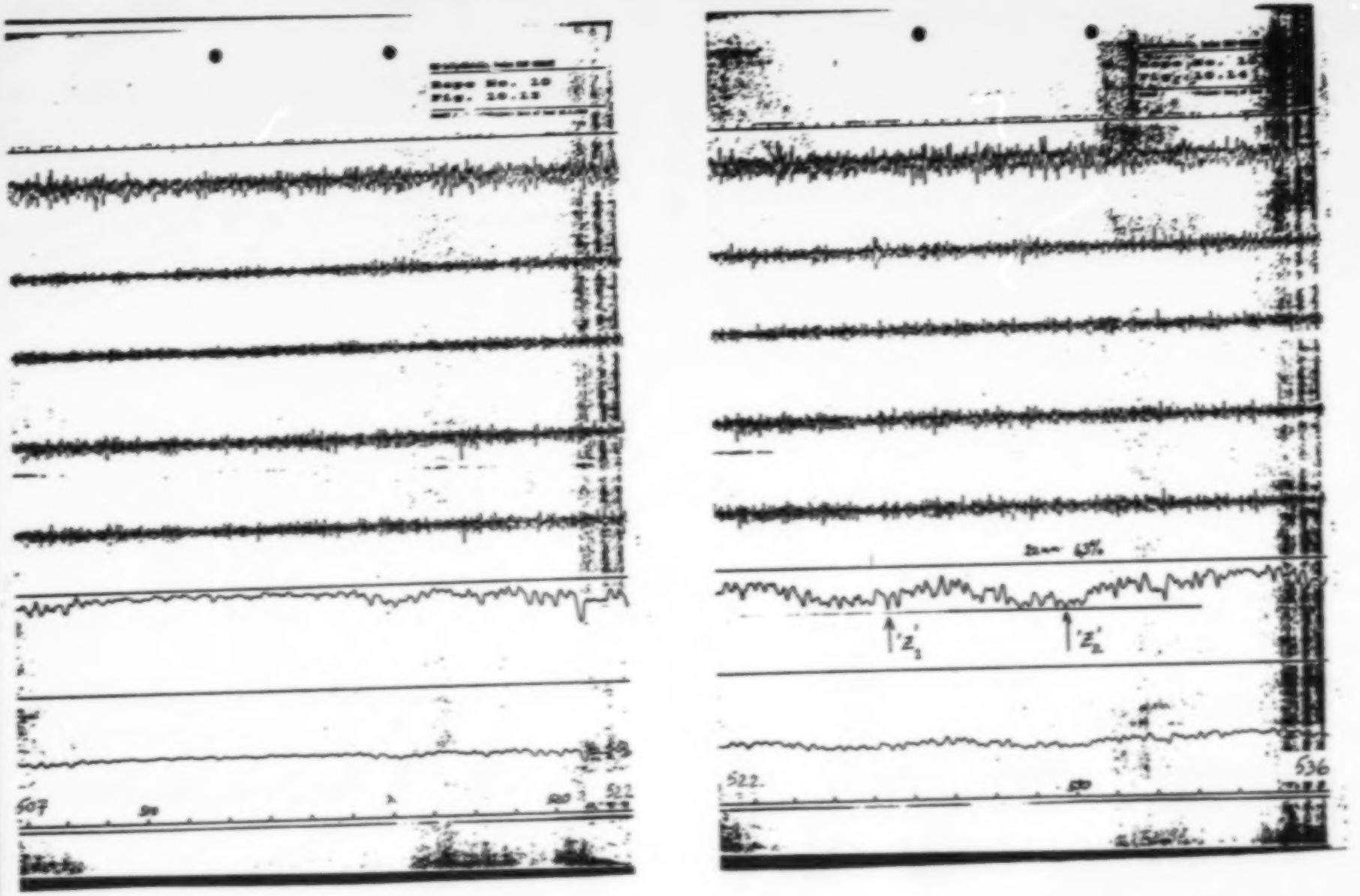


Fig. 5 (continued) — WBK shop-floor test of 1969 04 10

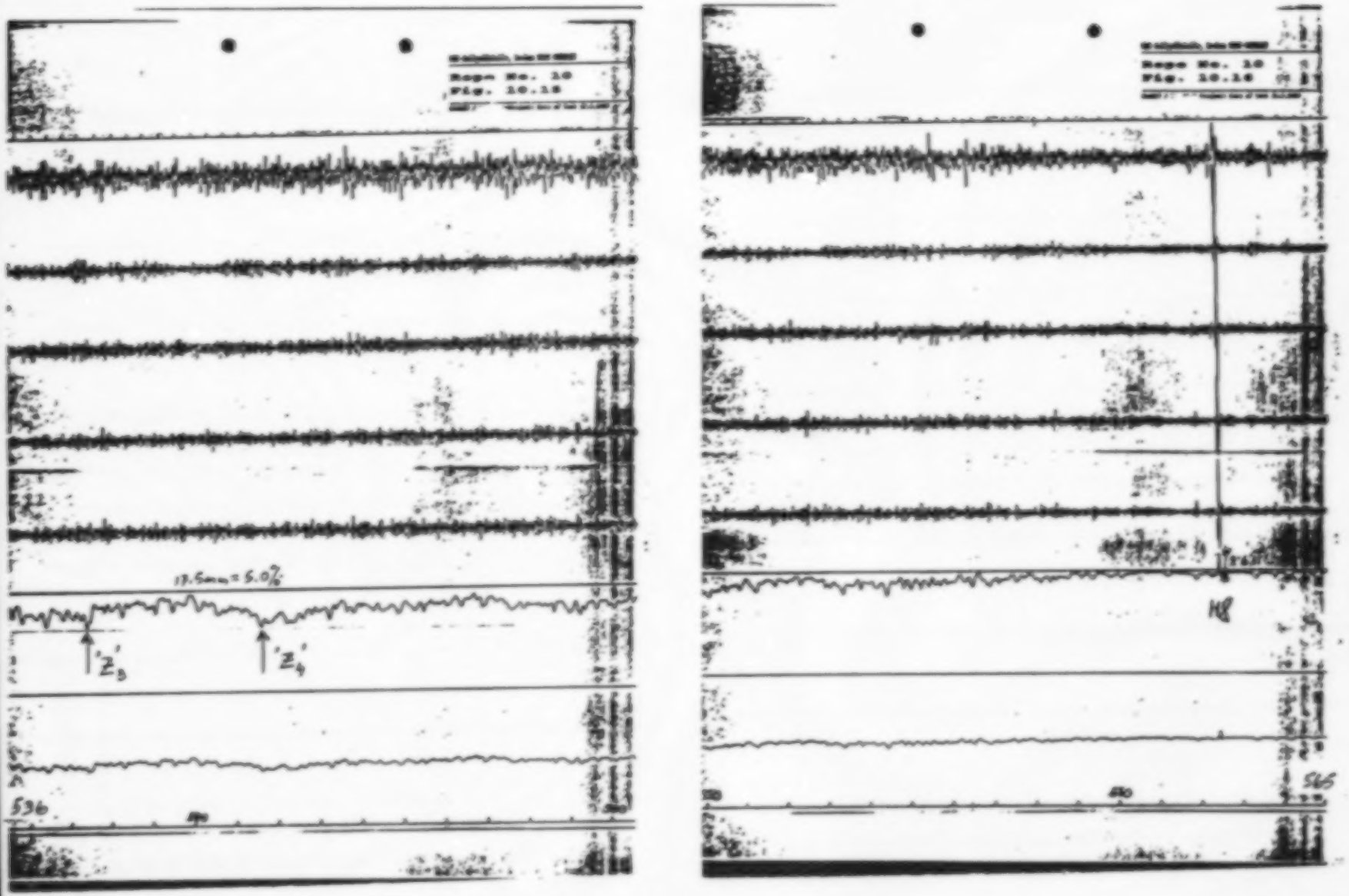


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

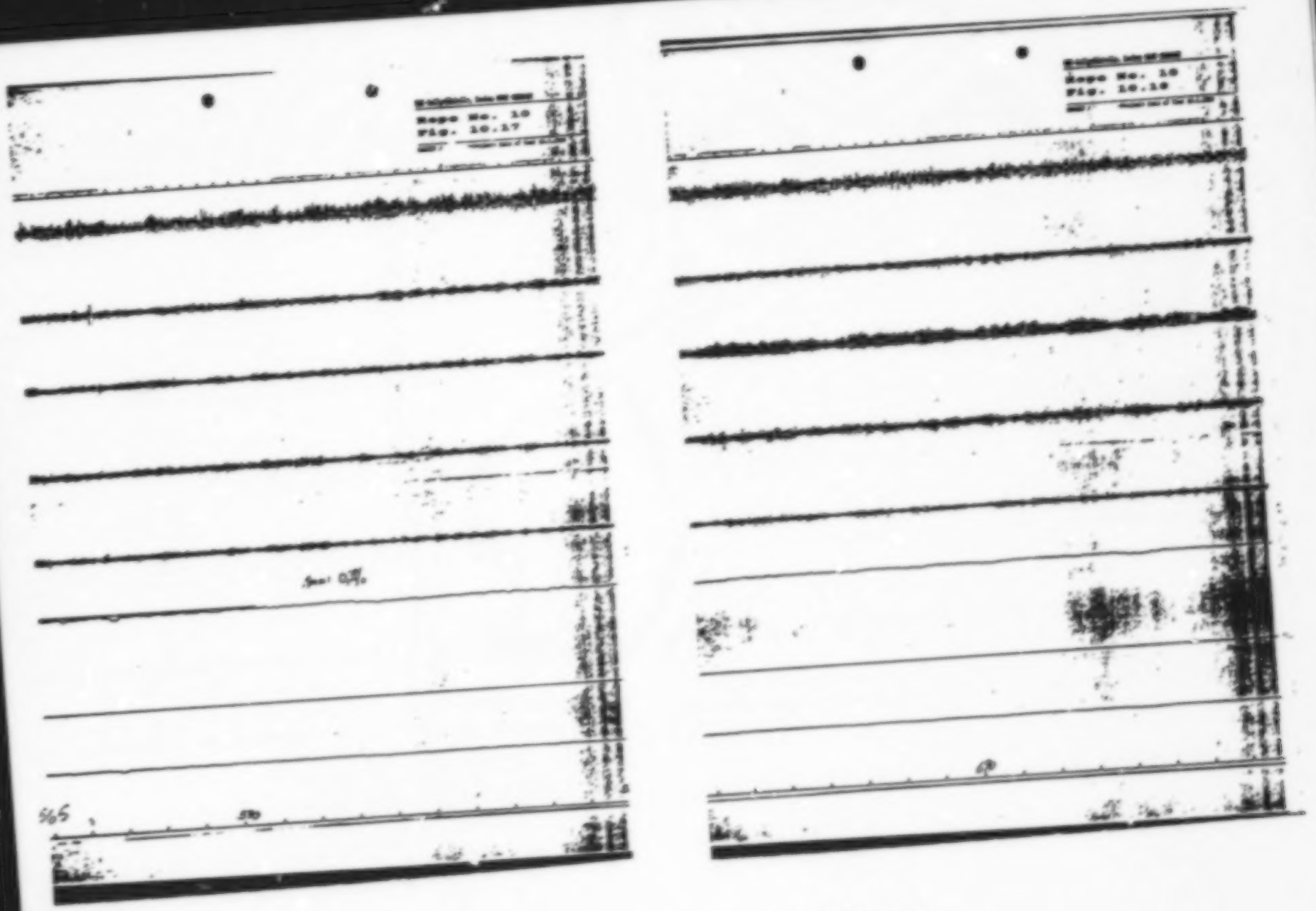


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

Fig. 5 (continued) — WBK shop-floor test of 1989 04 10

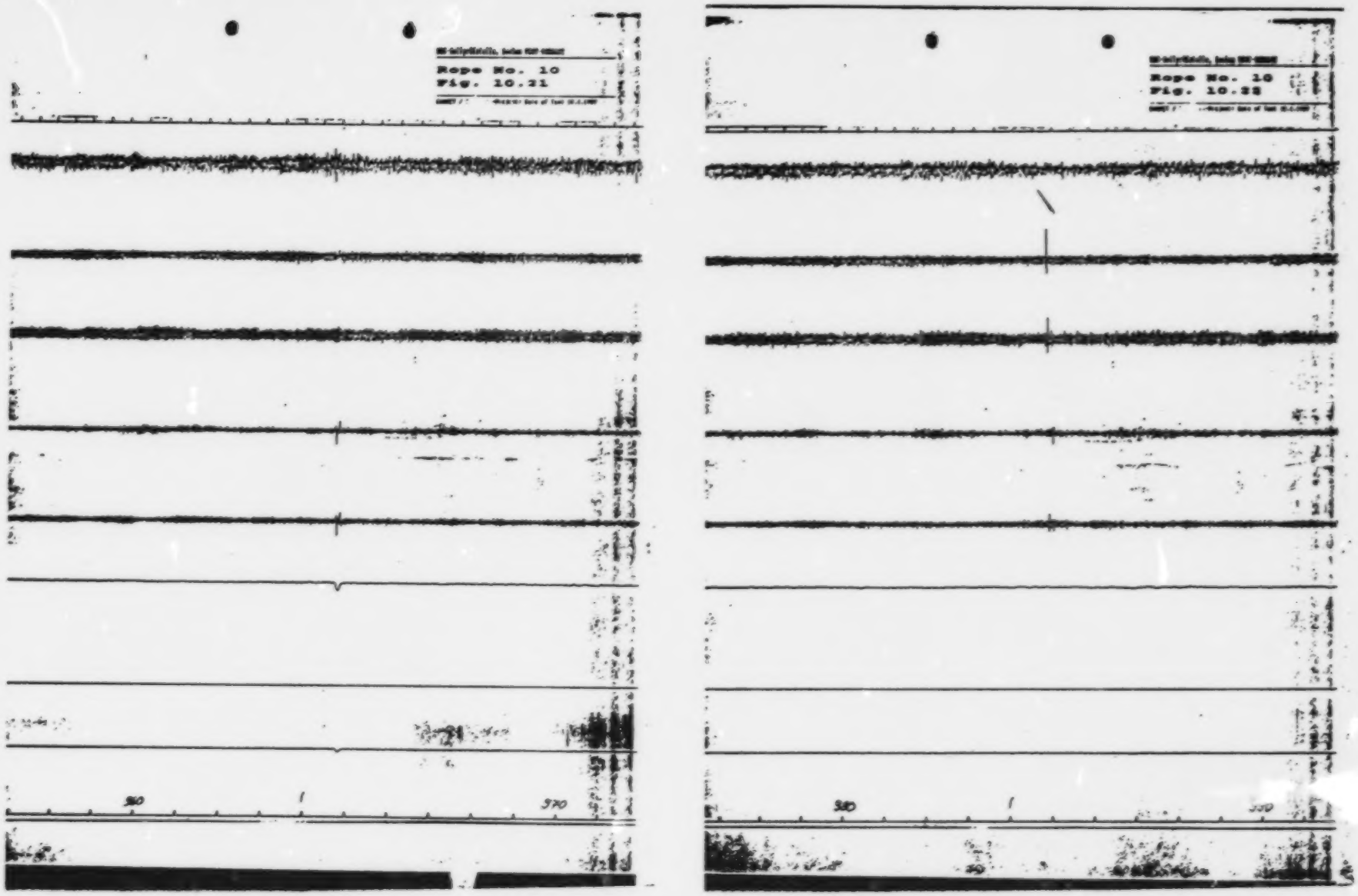
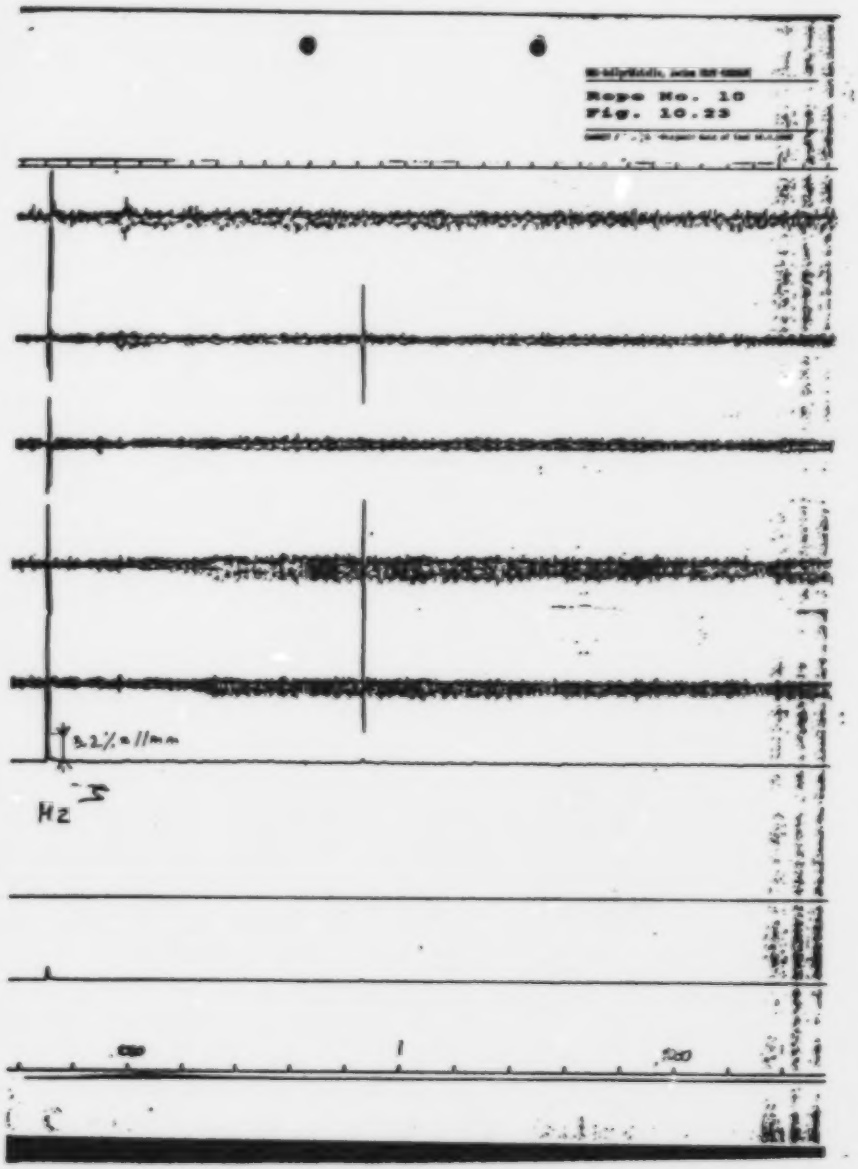


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10



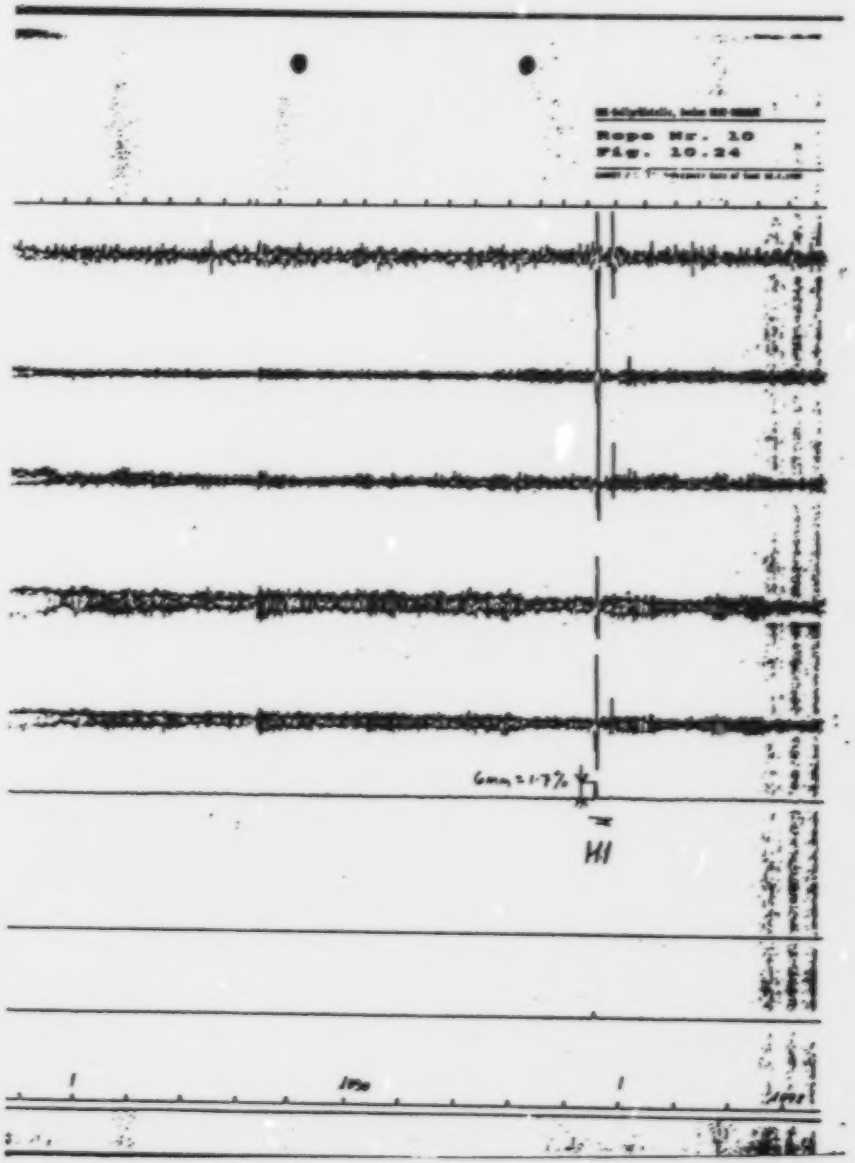


Fig. 5 (continued) — WBK shop-floor test of 1989 04 10